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Anisimovich et al.

(10) **Patent No.: US 9,471,562 B2**
(45) **Date of Patent: Oct. 18, 2016**

(54) **METHOD AND SYSTEM FOR ANALYZING AND TRANSLATING VARIOUS LANGUAGES WITH USE OF SEMANTIC HIERARCHY**

(75) Inventors: **Konstantin Anisimovich**, Moscow (RU); **Vladimir Selegey**, Moscow (RU); **Konstantin Zuev**, Moscow (RU)

(73) Assignee: **ABBYY InfoPoisk LLC** (RU)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1071 days.

(21) Appl. No.: **13/288,953**

(22) Filed: **Nov. 3, 2011**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation-in-part of application No. 11/548,214, filed on Oct. 10, 2006, now Pat. No. 8,078,450.

(51) **Int. Cl.**
G06F 17/27 (2006.01)
G06F 17/28 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 17/277*** (2013.01); ***G06F 17/271*** (2013.01); ***G06F 17/2755*** (2013.01); ***G06F 17/2785*** (2013.01); ***G06F 17/2872*** (2013.01)

(58) **Field of Classification Search**
CPC G06F 17/27; G06F 17/28
USPC 704/2–8
See application file for complete search history.

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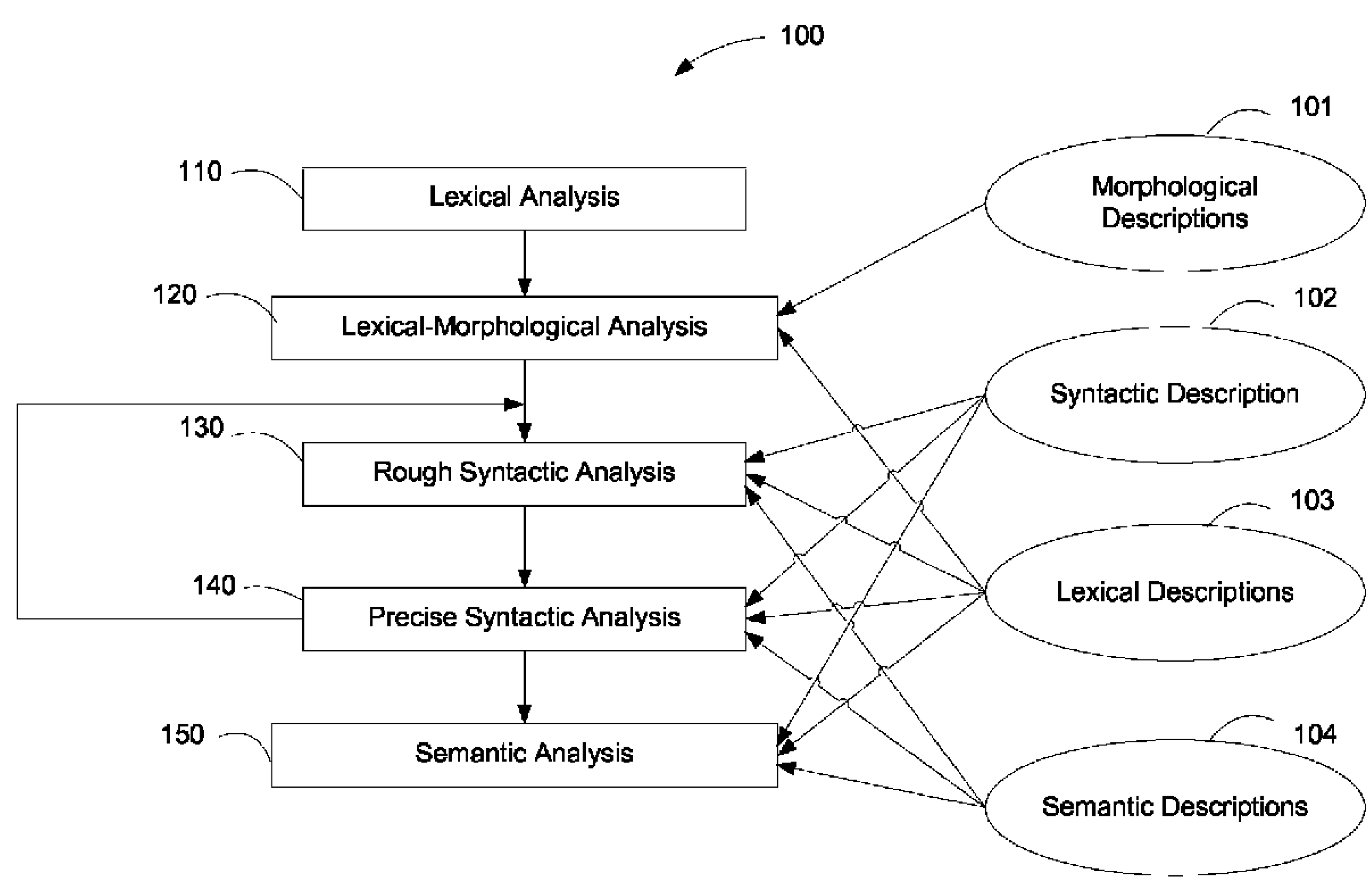
Primary Examiner — Jesse Pullias
(74) *Attorney, Agent, or Firm* — Veronica Weinstein

(57) **ABSTRACT**

A method and computer system for analyzing sentences of various languages and constructing a language-independent semantic structure are provided. On the basis of comprehensive knowledge about languages and semantics, exhaustive linguistic descriptions are created, and lexical, morphological, syntactic, and semantic analyses for one or more sentences of a natural or artificial language are performed. A computer system is also provided to implement, analyze and store various linguistic structures and to perform lexical, morphological, syntactic, and semantic analyses. As result, a generalized data structure, such as a semantic structure, is generated and used to describe the meaning of one or more sentences in language-independent form, applicable to automated abstracting, machine translation, control systems, Internet information retrieval, etc.

18 Claims, 27 Drawing Sheets



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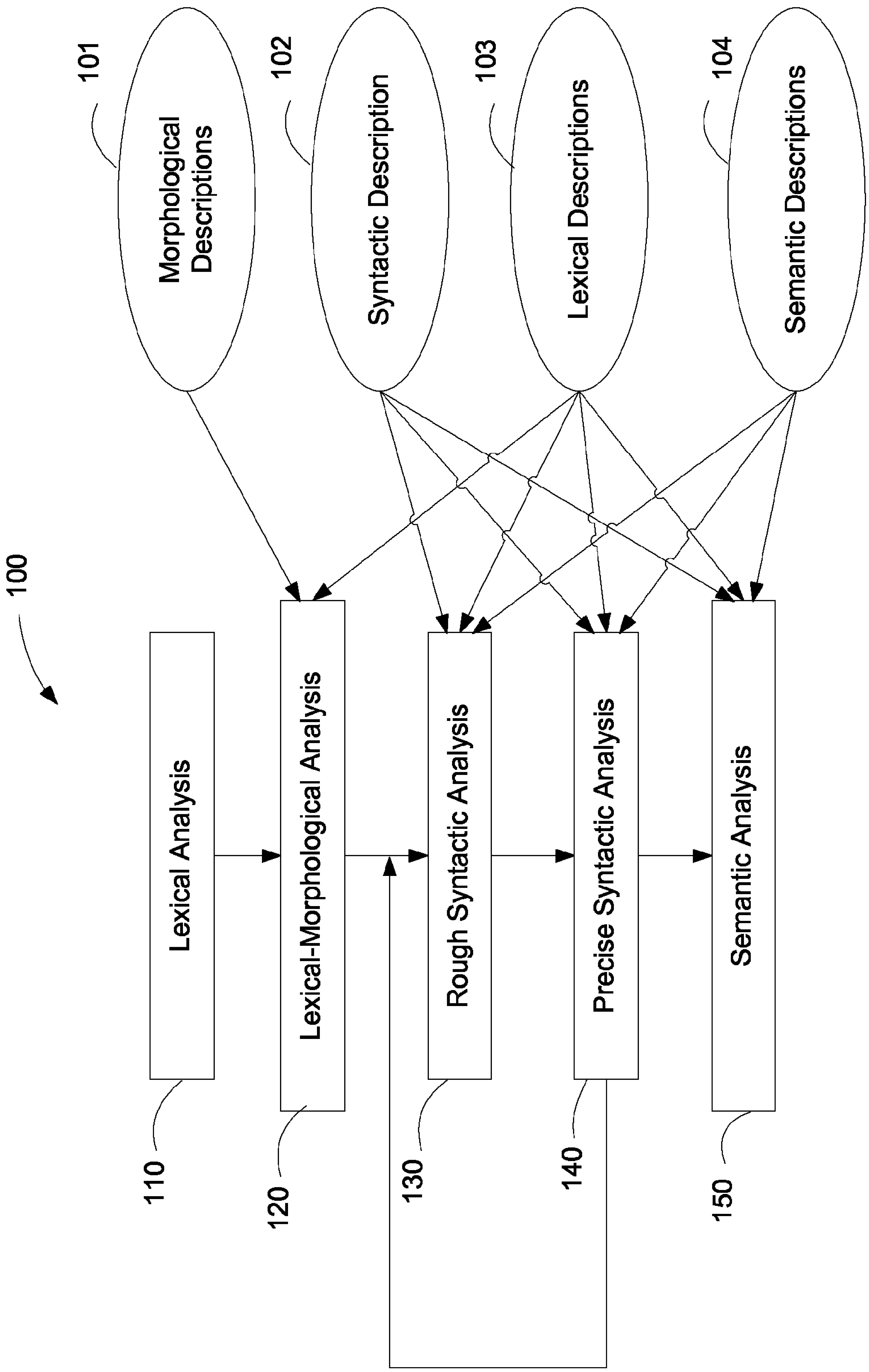
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101
Morphological Descriptions
102
Syntactic Description
103
Lexical Descriptions
104
Semantic Descriptions
Lexical Analysis
110
Lexical-Morphological Analysis
120
Rough Syntactic Analysis
130
Precise Syntactic Analysis
140
Semantic Analysis
150

Figure 1

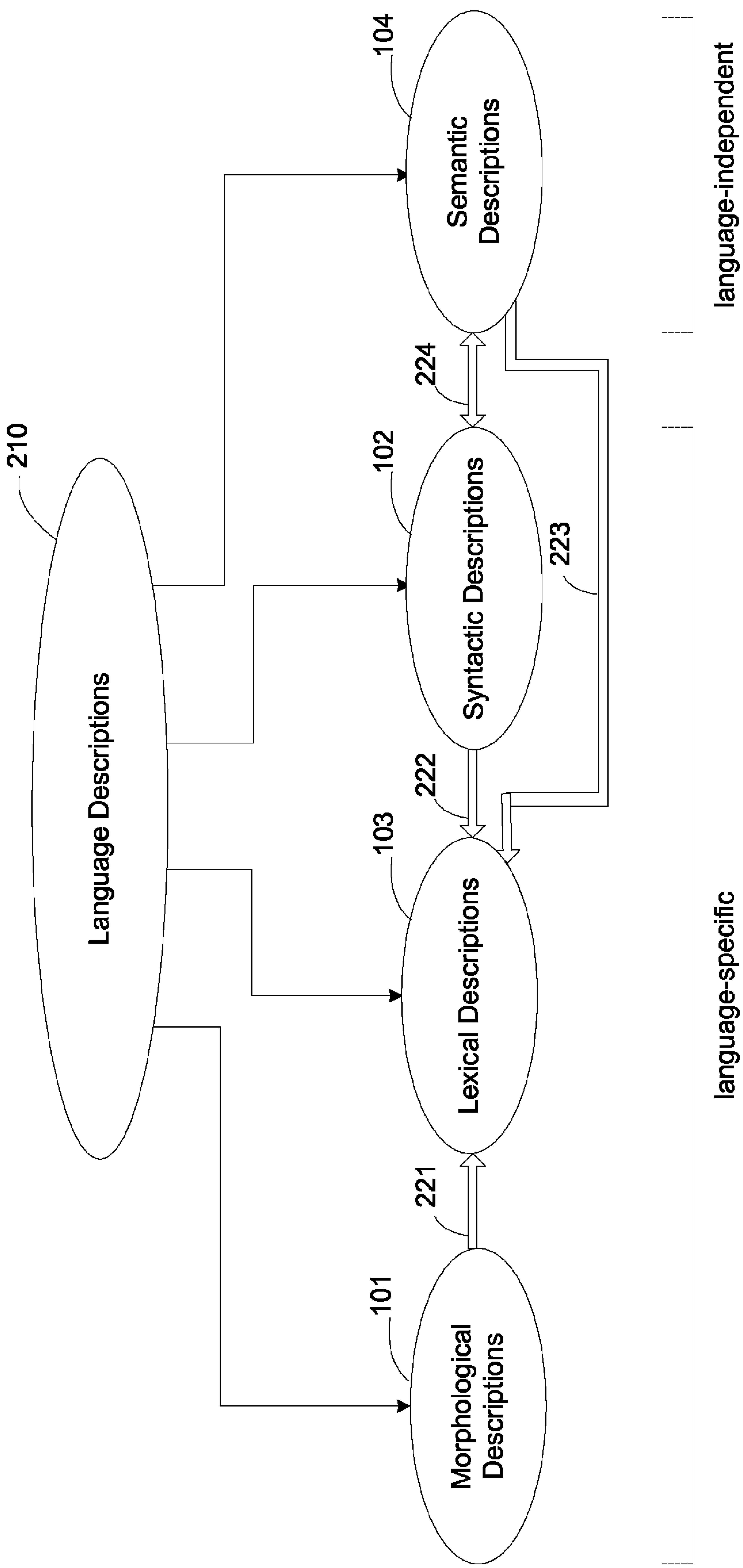

210
Language Descriptions
104
Semantic Descriptions
224
102
Syntactic Descriptions
223
222
103
Lexical Descriptions
221
101
Morphological Descriptions
language-independent
language-specific

Figure 2

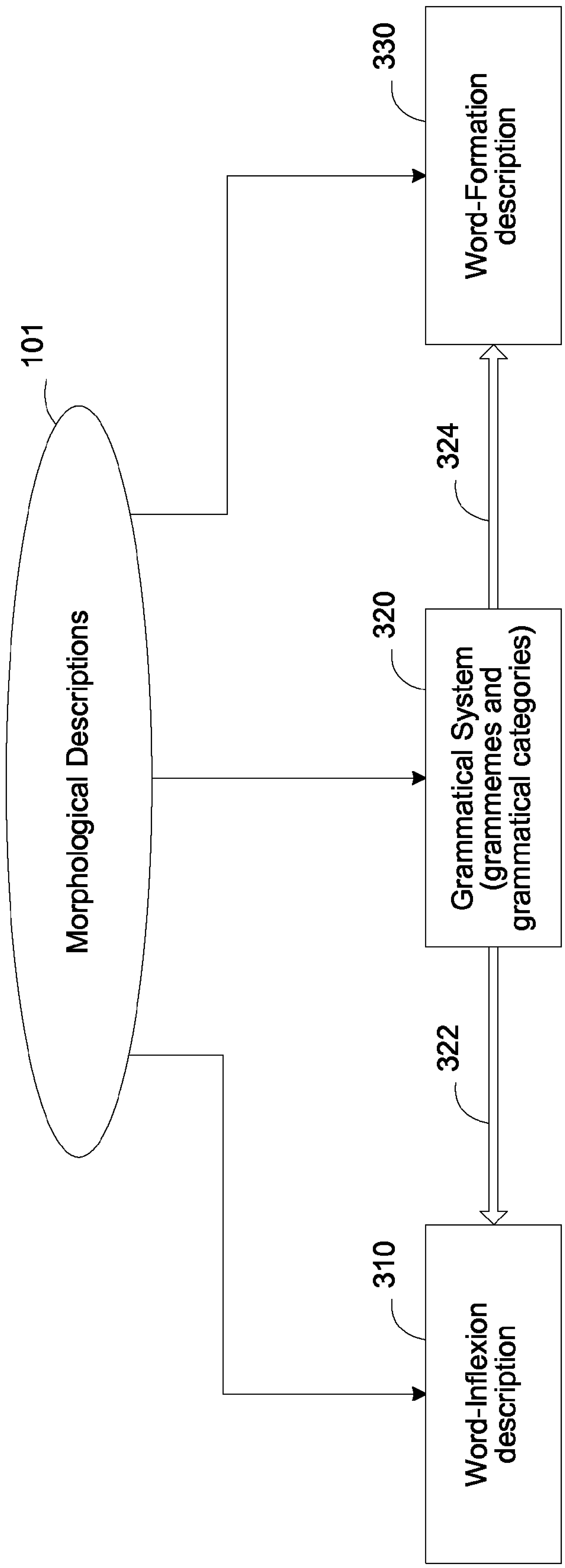
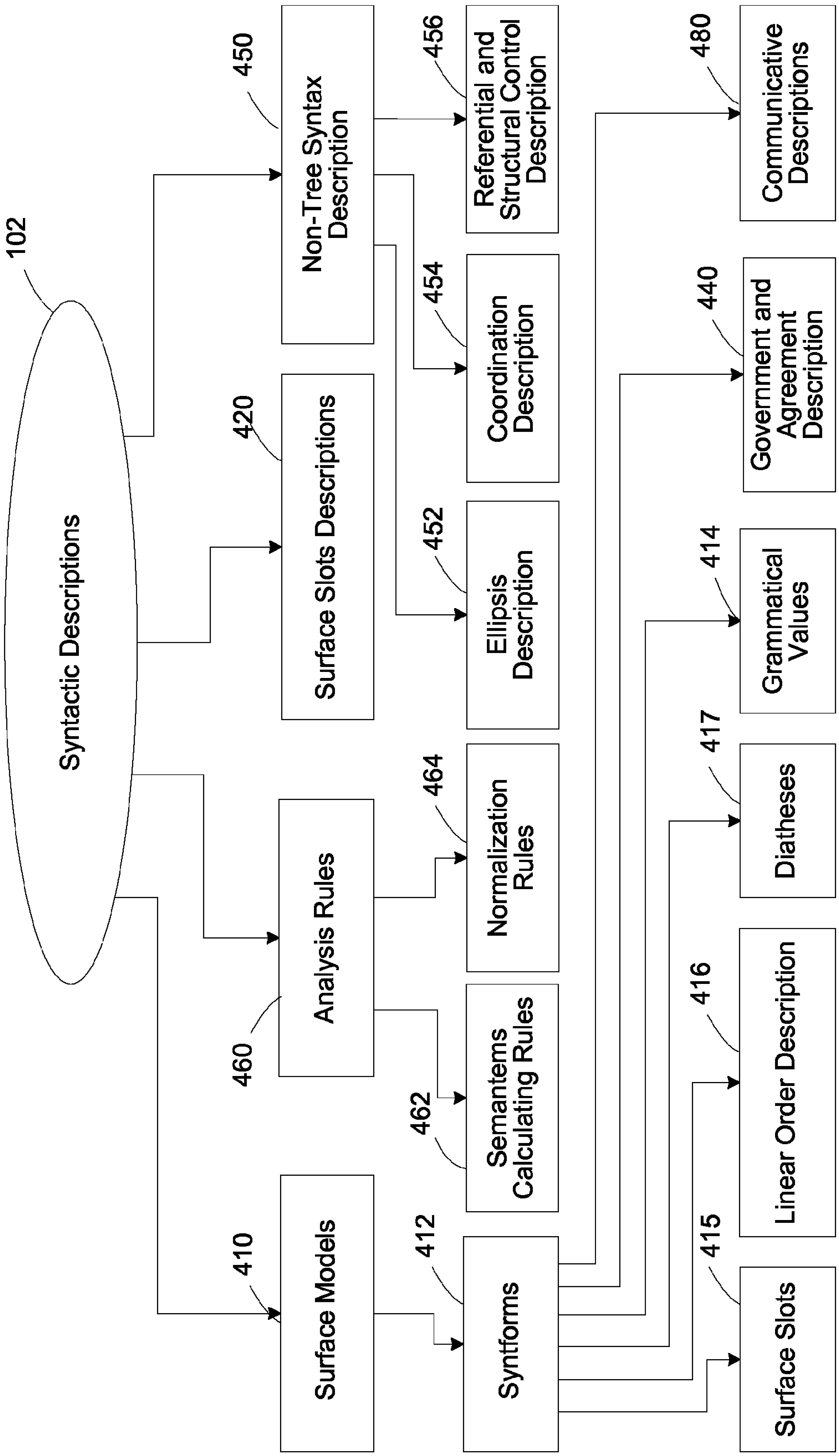

101
Morphological Descriptions
330
Word-Formation description
324
320
Grammatical System (grammemes and grammatical categories)
322
310
Word-Inflexion description

Figure 3



102
Syntactic Descriptions
410
Surface Models
412
Syntforms
415
Surface Slots
416
Linear Order Description
417
Diatheses
414
Grammatical Values
440
Government and Agreement Description
480
Communicative Descriptions
460
Analysis Rules
462
Semantems Calculating Rules
464
Normalization Rules
420
Surface Slots Descriptions
450
Non-Tree Syntax Description
452
Ellipsis Description
454
Coordination Description
456
Referential and Structural Control Description

Figure 4

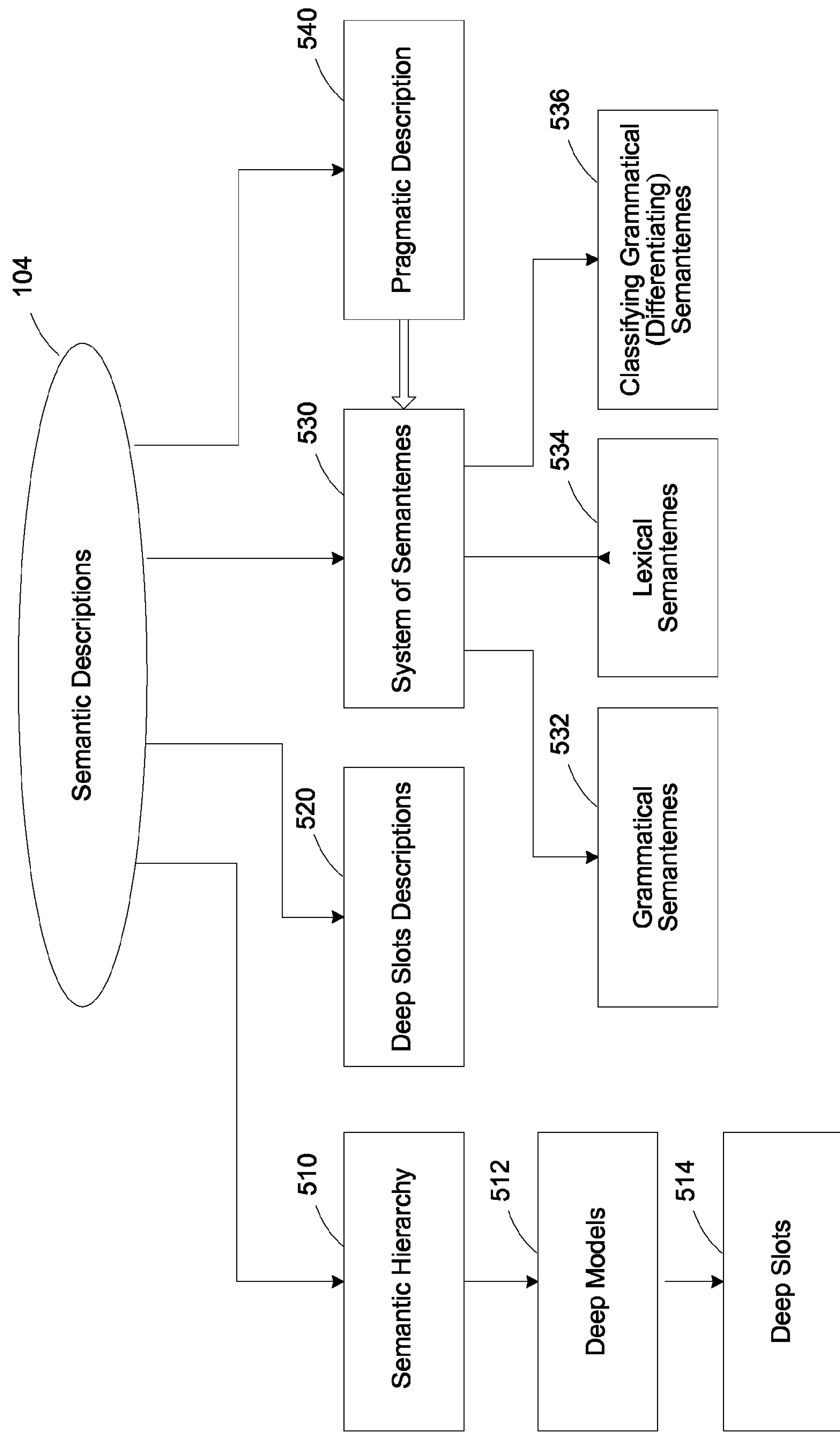

104
Semantic Descriptions
540
Pragmatic Description
530
System of Semantemes
536
Classifying Grammatical (Differentiating) Semantemes
534
Lexical Semantemes
532
Grammatical Semantemes
520
Deep Slots Descriptions
510
Semantic Hierarchy
512
Deep Models
514
Deep Slots

Figure 5

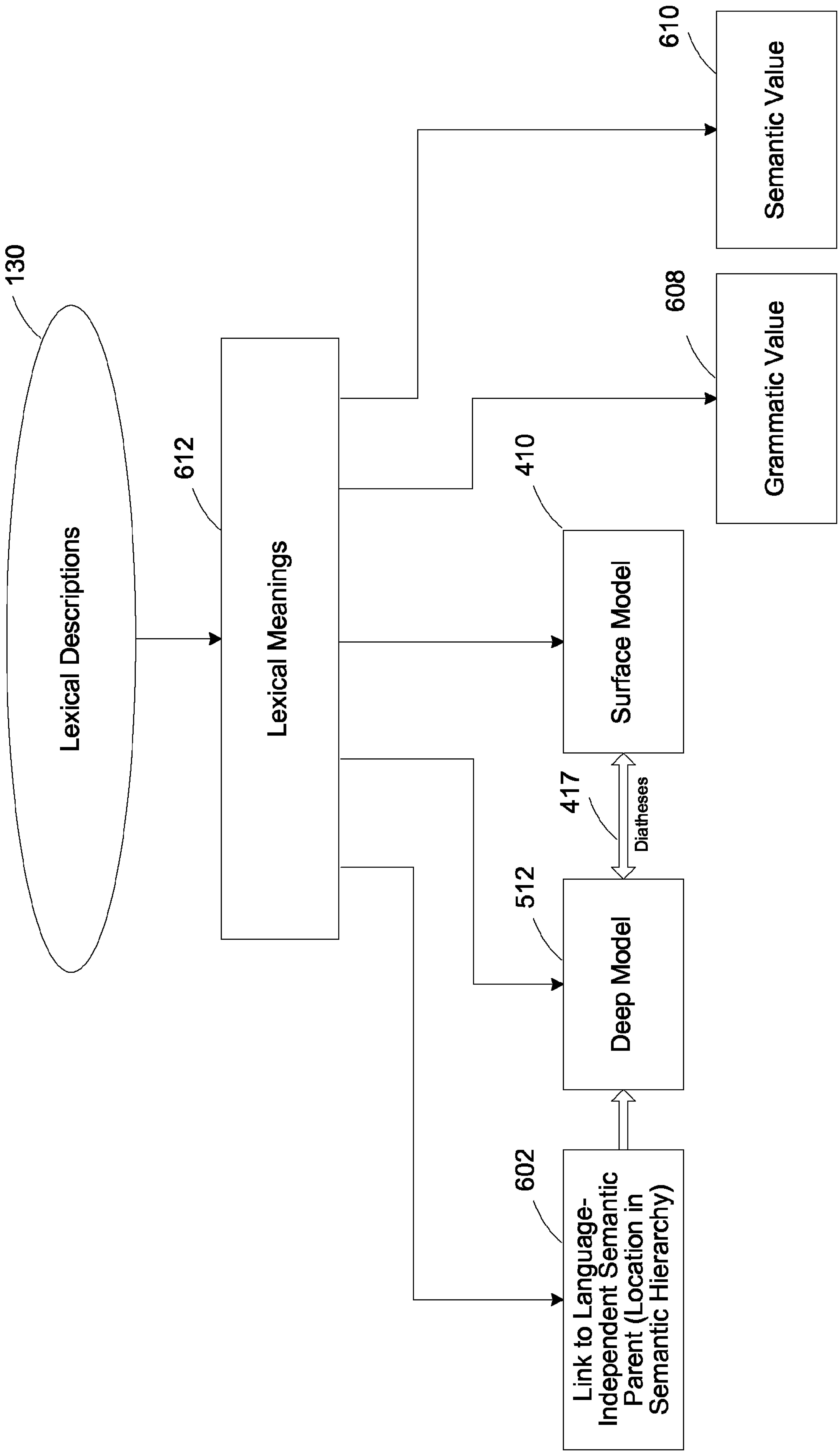
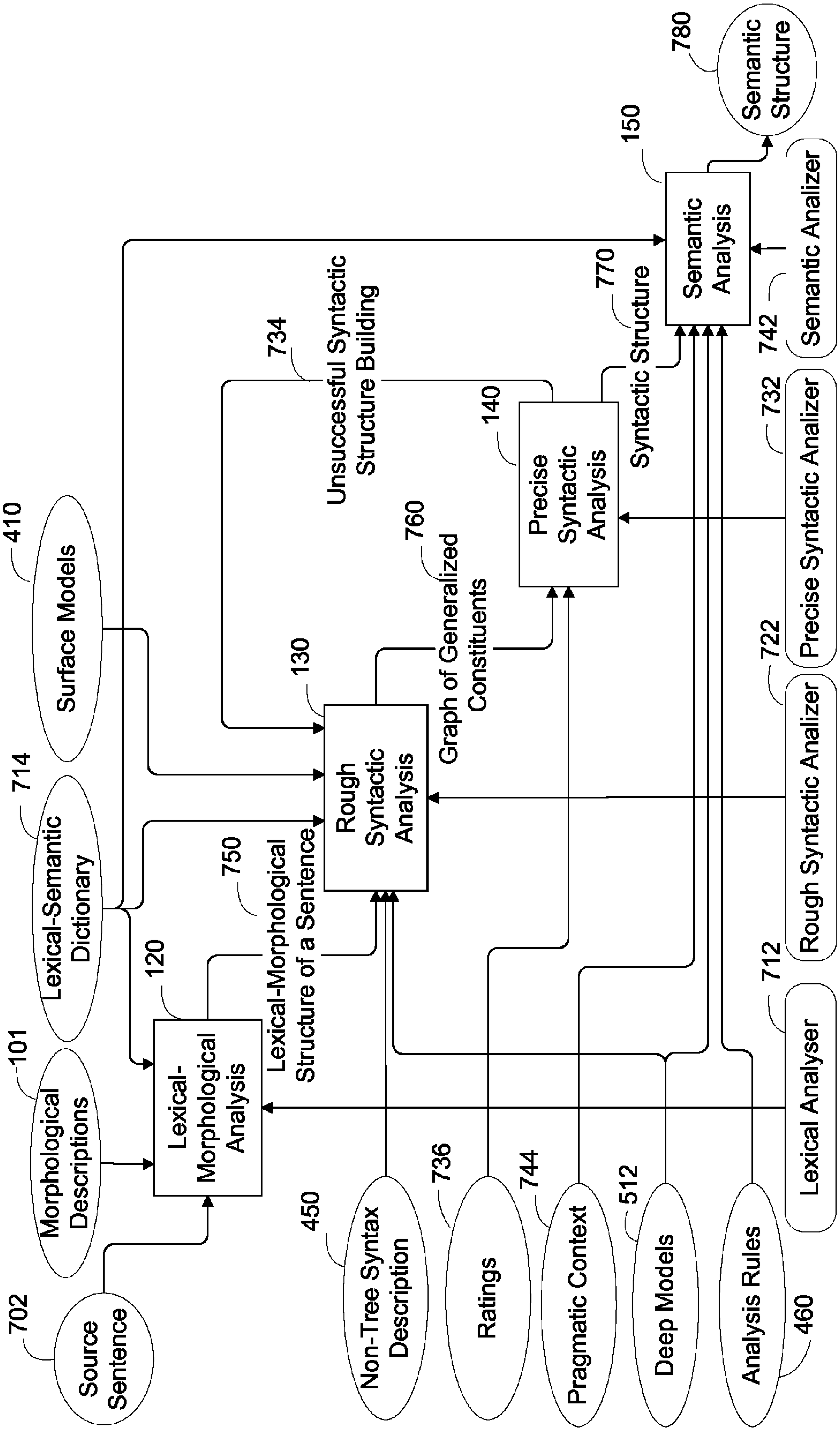

130
Lexical Descriptions
612
Lexical Meanings
610
Semantic Value
608
Grammatic Value
410
Surface Model
417
Diatheses
512
Deep Model
602
Link to Language-Independent Semantic Parent (Location in Semantic Hierarchy)

Figure 6



Source Sentence
702
Morphological Descriptions
101
Lexical-Morphological Analysis
120
Lexical-Semantic Dictionary
714
Surface Models
410
Lexical-Morphological Structure of a Sentence
750
Rough Syntactic Analysis
130
Graph of Generalized Constituents
760
Unsuccessful Syntactic Structure Building
734
Precise Syntactic Analysis
140
Syntactic Structure
770
Semantic Analysis
150
Semantic Structure
780
Non-Tree Syntax Description
450
Ratings
736
Pragmatic Context
744
Deep Models
512
Analysis Rules
460
Lexical Analyser
712
Rough Syntactic Analizer
722
Precise Syntactic Analizer
732
Semantic Analizer
742

Figure 7

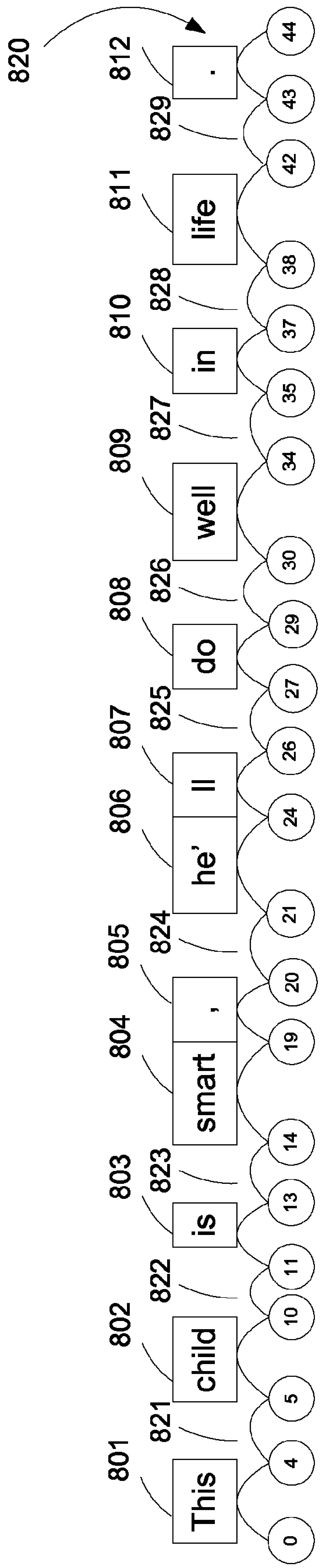

820
801
This
821
802
child
822
803
is
823
804
smart
805
,
824
806
he'
807
ll
825
808
do
826
809
well
827
810
in
828
811
life
829
812
.
0
4
5
10
11
13
14
19
20
21
24
26
27
29
30
34
35
37
38
42
43
44

Figure 8

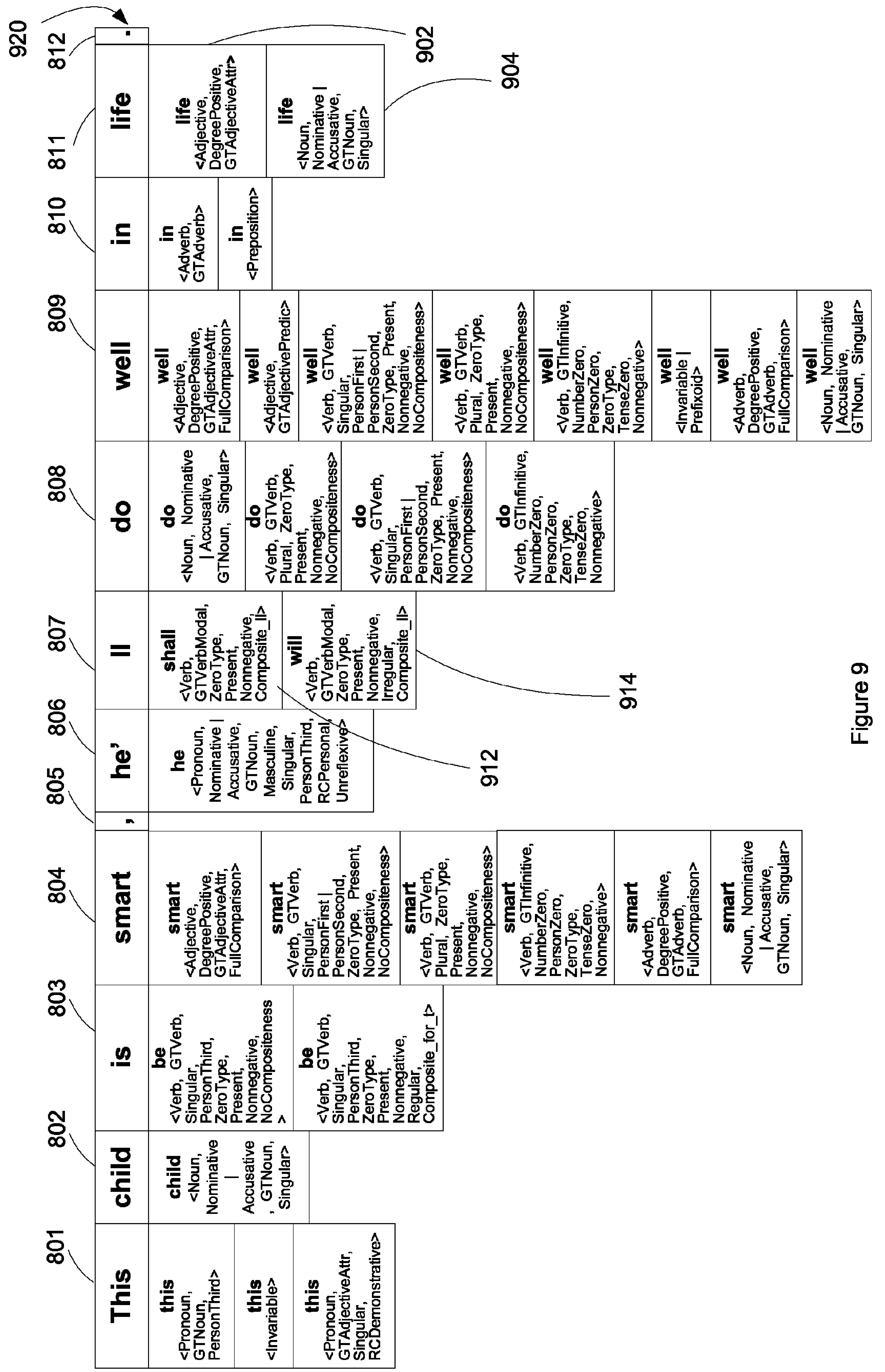

920
902
904
912
914
801
This
this <Pronoun, GTNoun, PersonThird>
this <Invariable>
this <Pronoun, GTAdjectiveAttr, Singular, RCDemonstrative>
802
child
child <Noun, Nominative | Accusative , GTNoun, Singular>
803
is
be <Verb, GTVerb, Singular, PersonThird, ZeroType, Present, Nonnegative, NoCompositeness >
be <Verb, GTVerb, Singular, PersonThird, ZeroType, Present, Nonnegative, Regular, Composite_for_t>
804
smart
smart <Adjective, DegreePositive, GTAdjectiveAttr, FullComparison>
smart <Verb, GTVerb, Singular, PersonFirst | PersonSecond, ZeroType, Present, Nonnegative, NoCompositeness>
smart <Verb, GTVerb, Plural, ZeroType, Present, Nonnegative, NoCompositeness>
smart <Verb, GTInfinitive, NumberZero, PersonZero, ZeroType, TenseZero, Nonnegative>
smart <Adverb, DegreePositive, GTAdverb, FullComparison>
smart <Noun, Nominative | Accusative, GTNoun, Singular>
805
,
806
he'
he <Pronoun, Nominative | Accusative, GTNoun, Masculine, Singular, PersonThird, RCPersonal, Unreflexive>
807
ll
shall <Verb, GTVerbModal, ZeroType, Present, Nonnegative, Composite_ll>
will <Verb, GTVerbModal, ZeroType, Present, Nonnegative, Irregular, Composite_ll>
808
do
do <Noun, Nominative | Accusative, GTNoun, Singular>
do <Verb, GTVerb, Plural, ZeroType, Present, Nonnegative, NoCompositeness>
do <Verb, GTVerb, Singular, PersonFirst | PersonSecond, ZeroType, Present, Nonnegative, NoCompositeness>
do <Verb, GTInfinitive, NumberZero, PersonZero, ZeroType, TenseZero, Nonnegative>
809
well
well <Adjective, DegreePositive, GTAdjectiveAttr, FullComparison>
well <Adjective, GTAdjectivePredic>
well <Verb, GTVerb, Singular, PersonFirst | PersonSecond, ZeroType, Present, Nonnegative, NoCompositeness>
well <Verb, GTVerb, Plural, ZeroType, Present, Nonnegative, NoCompositeness>
well <Verb, GTInfinitive, NumberZero, PersonZero, ZeroType, TenseZero, Nonnegative>
well <Invariable | Prefixoid>
well <Adverb, DegreePositive, GTAdverb, FullComparison>
well <Noun, Nominative | Accusative, GTNoun, Singular>
810
in
in <Adverb, GTAdverb>
in <Preposition>
811
life
life <Adjective, DegreePositive, GTAdjectiveAttr>
life <Noun, Nominative | Accusative, GTNoun, Singular>
812
.

Figure 9

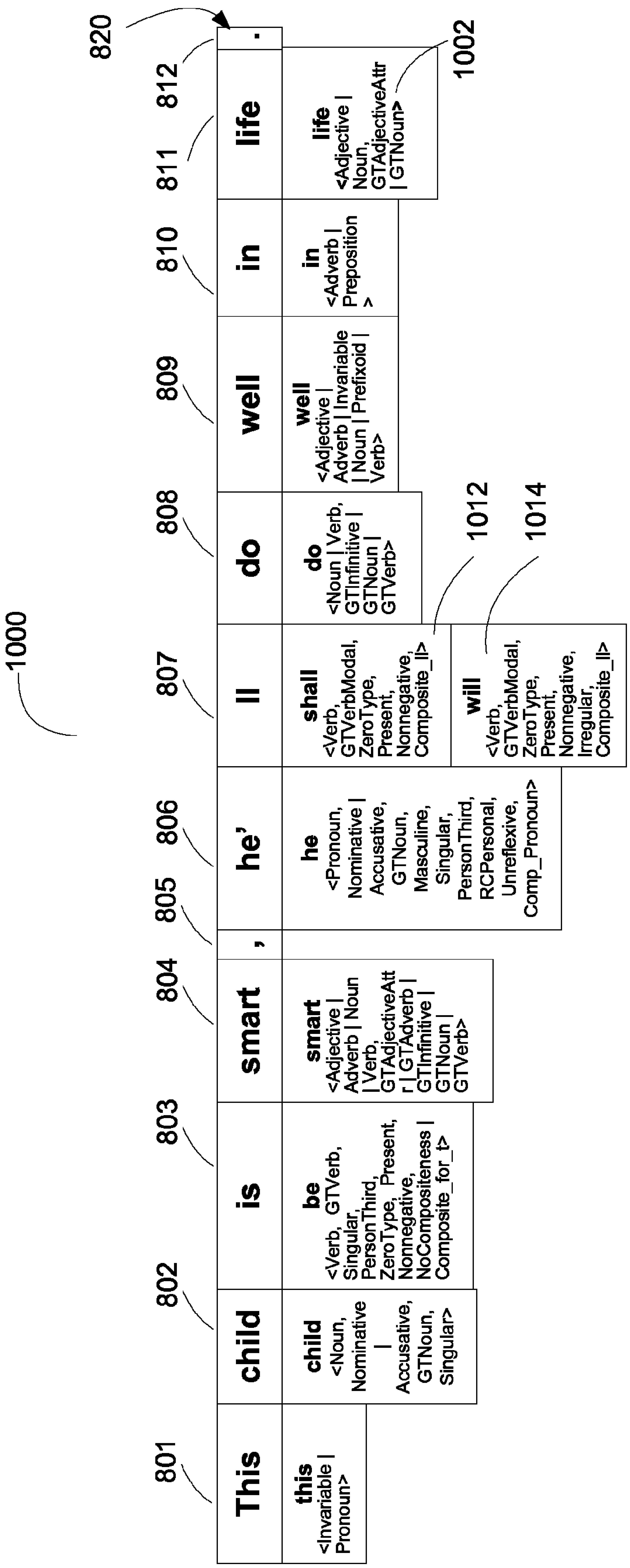

1000
801
802
803
804
805
806
807
808
809
810
811
812
820
This
child
is
smart
,
he'
ll
do
well
in
life
.
this <Invariable | Pronoun>
child <Noun, Nominative | Accusative, GTNoun, Singular>
be <Verb, GTVerb, Singular, PersonThird, ZeroType, Present, Nonnegative, NoCompositeness | Composite_for_t>
smart <Adjective | Adverb | Noun | Verb, GTAdjectiveAttr | GTAdverb | GTInfinitive | GTNoun | GTVerb>
he <Pronoun, Nominative | Accusative, GTNoun, Masculine, Singular, PersonThird, RCPersonal, Unreflexive, Comp_Pronoun>
shall <Verb, GTVerbModal, ZeroType, Present, Nonnegative, Composite_ll>
will <Verb, GTVerbModal, ZeroType, Present, Nonnegative, Irregular, Composite_ll>
1012
1014
do <Noun | Verb, GTInfinitive | GTNoun | GTVerb>
well <Adjective | Adverb | Invariable | Noun | Prefixoid | Verb>
in <Adverb | Preposition >
life <Adjective | Noun, GTAdjectiveAttr | GTNoun>
1002

Figure 10

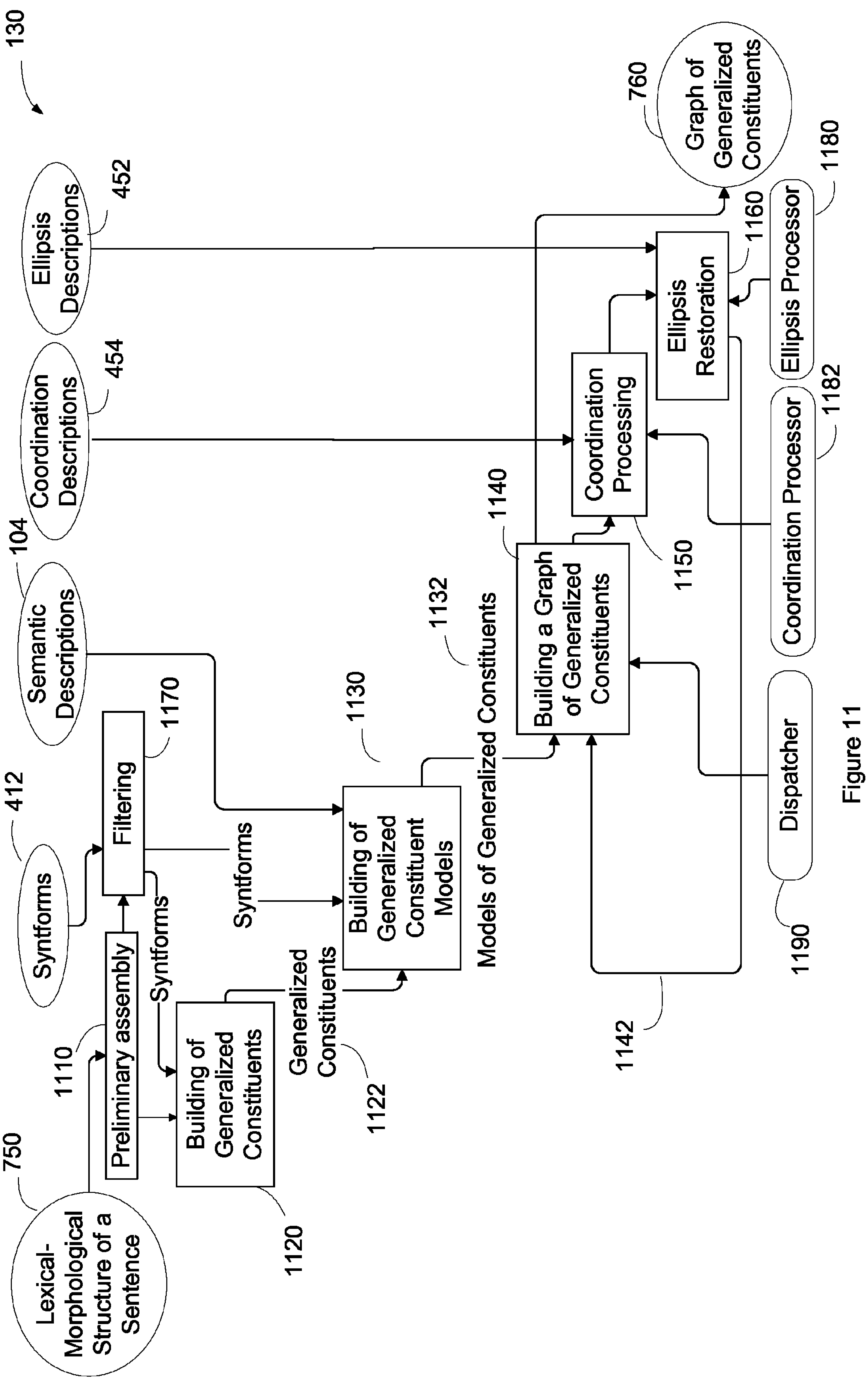

130
Lexical-Morphological Structure of a Sentence
750
Preliminary assembly
1110
Building of Generalized Constituents
1120
Syntforms
412
Filtering
1170
Syntforms
Syntforms
Generalized Constituents
1122
Semantic Descriptions
104
Building of Generalized Constituent Models
1130
Models of Generalized Constituents
1132
Coordination Descriptions
454
Ellipsis Descriptions
452
Building a Graph of Generalized Constituents
1140
1142
Coordination Processing
1150
Ellipsis Restoration
1160
Graph of Generalized Constituents
760
Dispatcher
1190
Coordination Processor
1182
Ellipsis Processor
1180

Figure 11

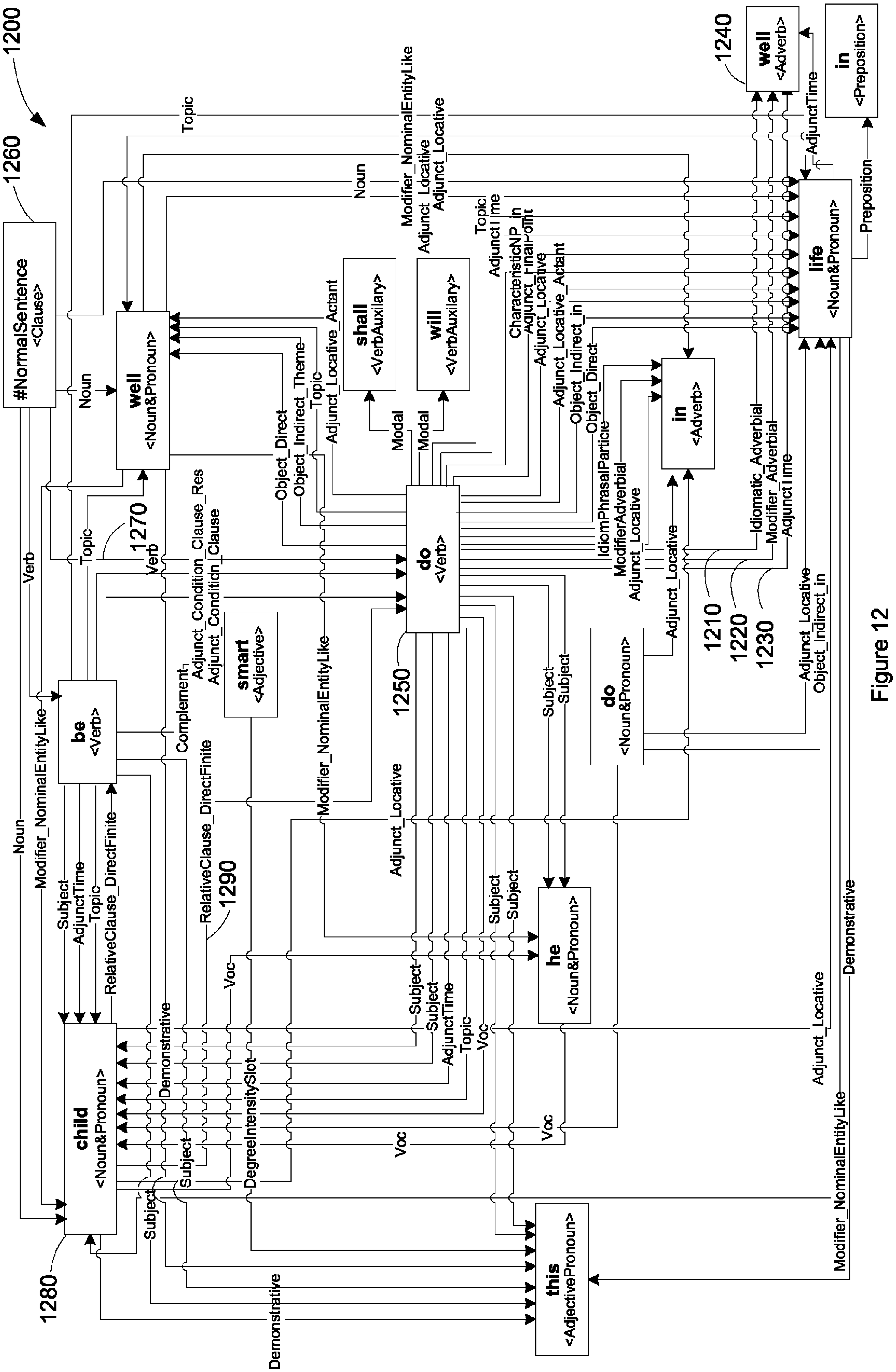

1200
1260
#NormalSentence
<Clause>
well
<Noun&Pronoun>
shall
<VerbAuxilary>
will
<VerbAuxilary>
in
<Adverb>
life
<Noun&Pronoun>
well
<Adverb>
in
<Preposition>
1240
do
<Verb>
1250
1270
be
<Verb>
smart
<Adjective>
do
<Noun&Pronoun>
he
<Noun&Pronoun>
child
<Noun&Pronoun>
this
<AdjectivePronoun>
1210
1220
1230
1280
1290
Topic
Noun
Verb
Modal
Subject
Voc
Demonstrative
Preposition
AdjunctTime
Adjunct_Locative
Object_Direct
Object_Indirect_in
Modifier_NominalEntityLike
Complement
RelativeClause_DirectFinite
DegreeIntensitySlot
Idiomatic_Adverbial
Modifier_Adverbial
IdiomPhrasalParticle
ModifierAdverbial
Adjunct_Condition_Clause_Res
Adjunct_Condition_Clause
Object_Indirect_Theme
Adjunct_Locative_Actant
CharacteristicNP_in
Adjunct_FinalPoint

Figure 12

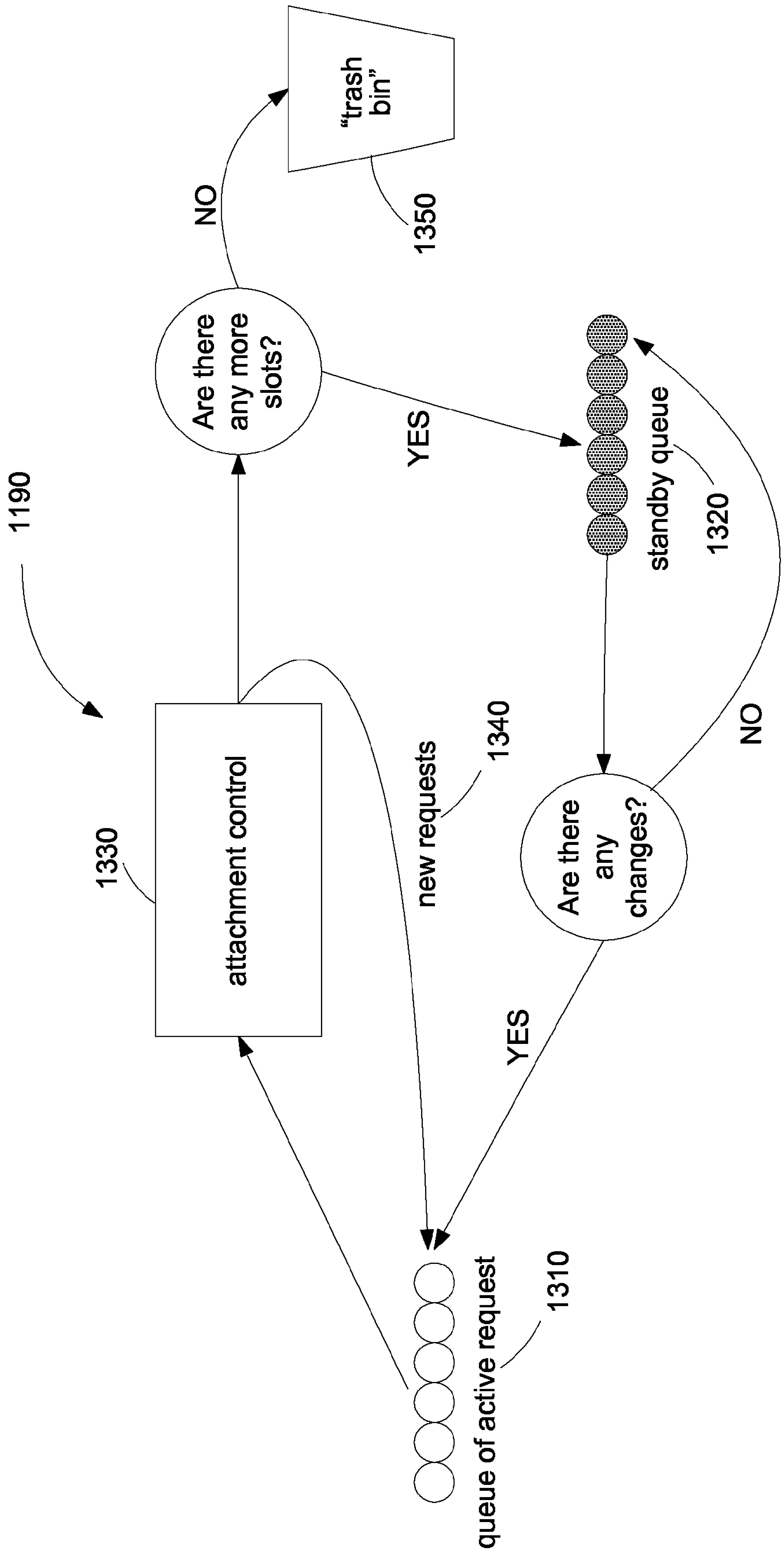

1190
attachment control
1330
new requests
1340
Are there any more slots?
NO
"trash bin"
1350
YES
standby queue
1320
Are there any changes?
NO
YES
queue of active request
1310

Figure 13

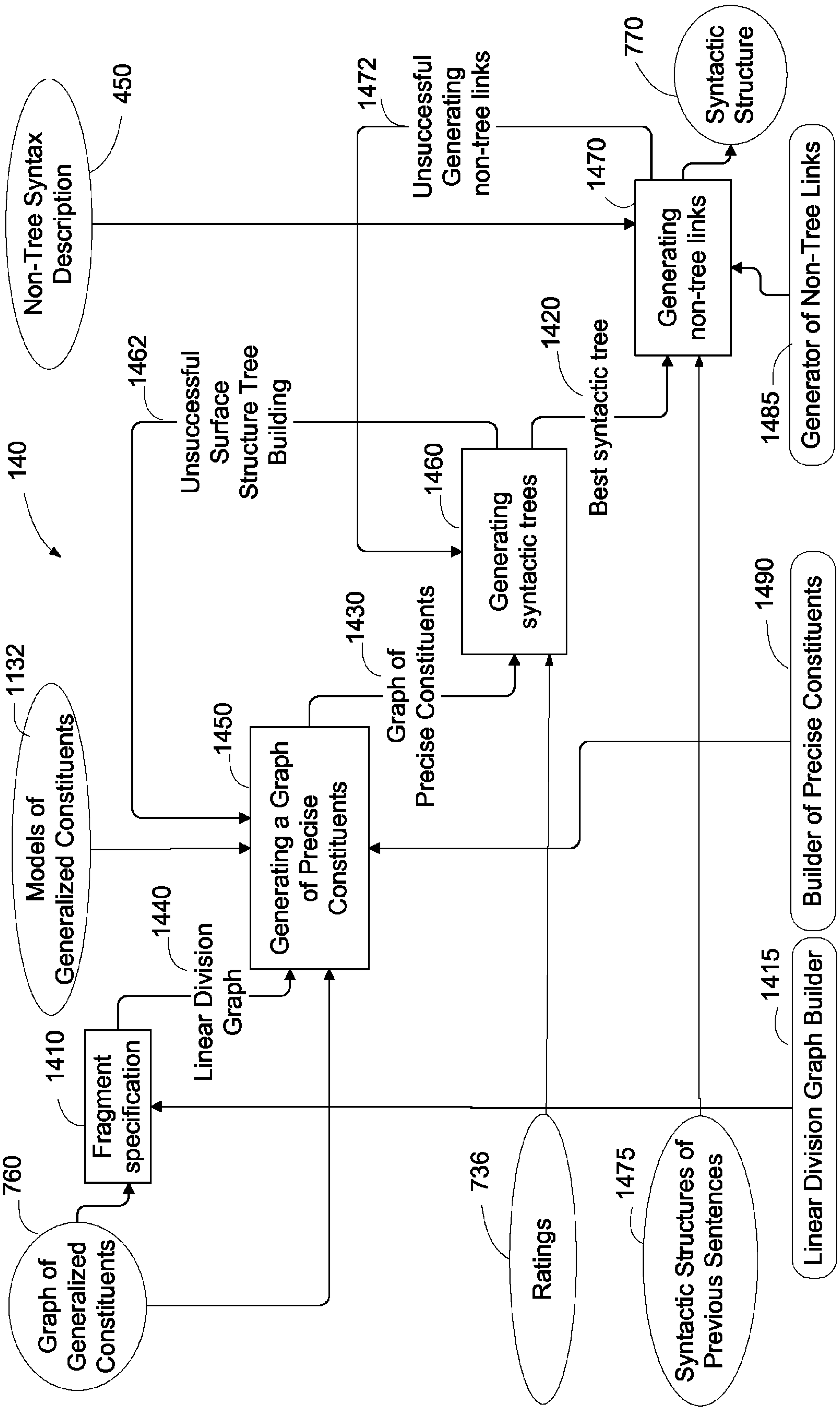

140
Graph of Generalized Constituents
760
Fragment specification
1410
Models of Generalized Constituents
1132
Linear Division Graph
1440
Generating a Graph of Precise Constituents
1450
Graph of Precise Constituents
1430
Generating syntactic trees
1460
Unsuccessful Surface Structure Tree Building
1462
Best syntactic tree
1420
Non-Tree Syntax Description
450
Generating non-tree links
1470
Unsuccessful Generating non-tree links
1472
Syntactic Structure
770
Ratings
736
Syntactic Structures of Previous Sentences
1475
Linear Division Graph Builder
1415
Builder of Precise Constituents
1490
Generator of Non-Tree Links
1485

Figure 14

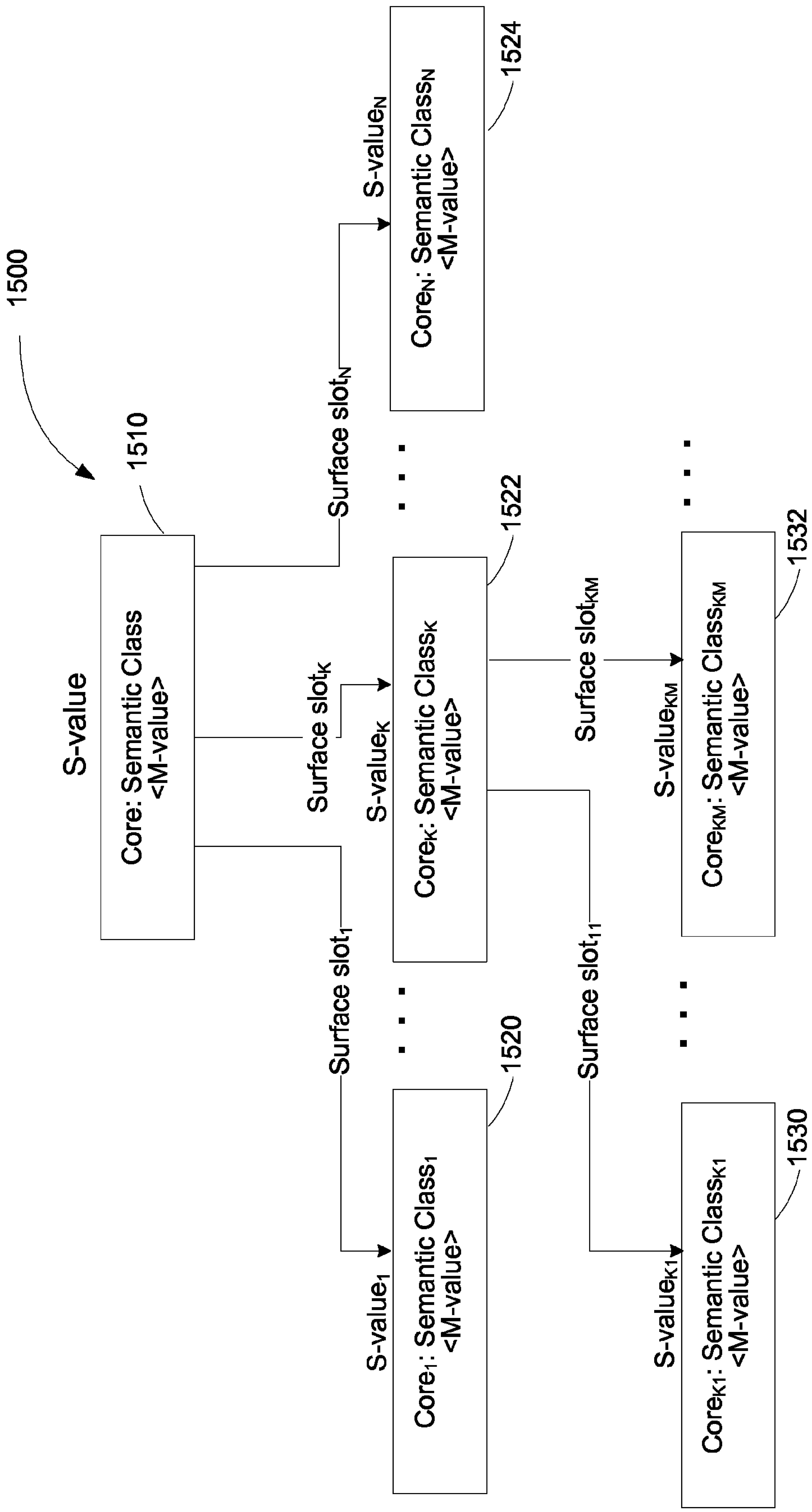
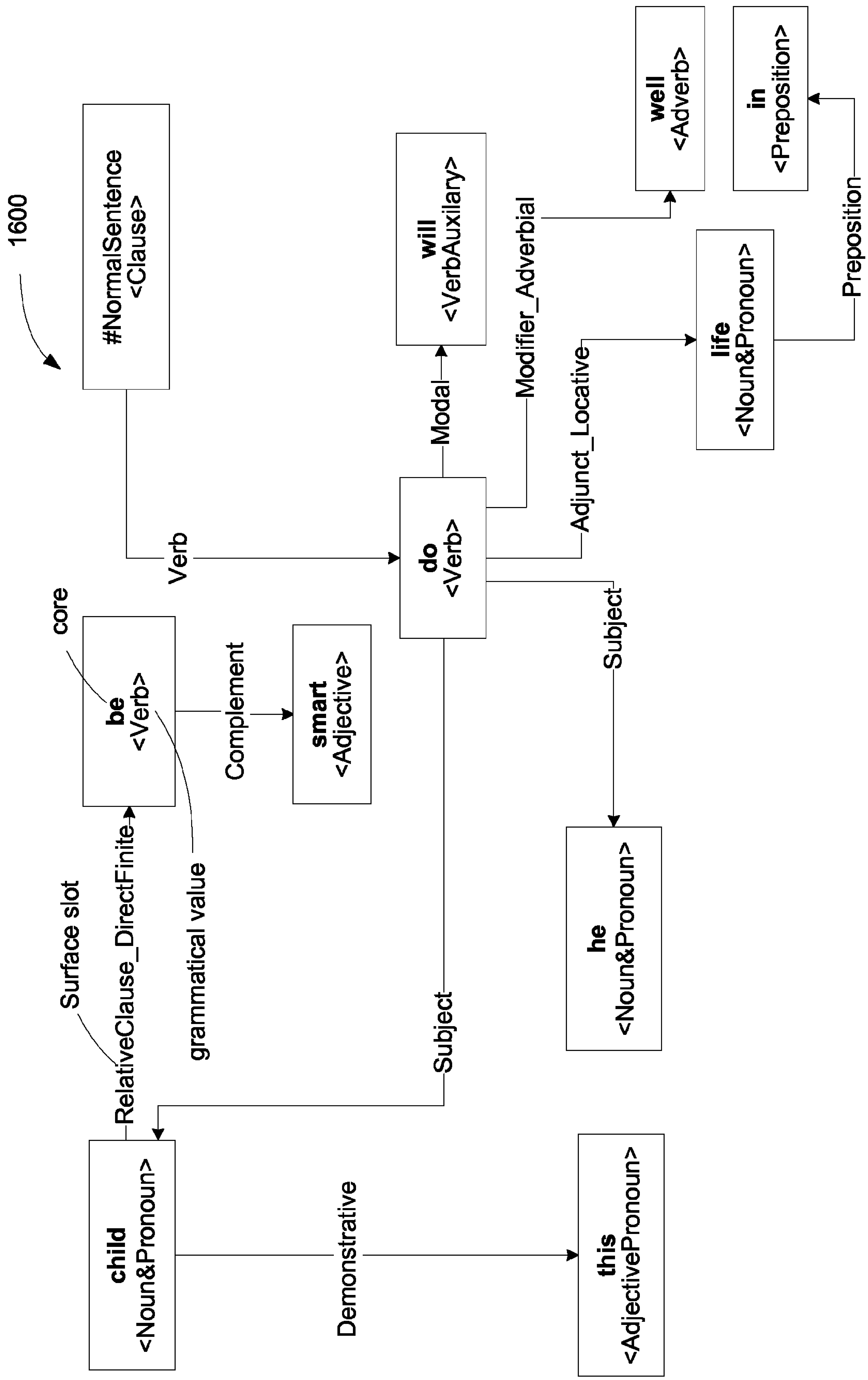

1500
S-value
Core: Semantic Class
<M-value>
1510
Surface slot$_1$
Surface slot$_K$
Surface slot$_N$
S-value$_1$
Core$_1$: Semantic Class$_1$
<M-value>
1520
S-value$_K$
Core$_K$: Semantic Class$_K$
<M-value>
1522
S-value$_N$
Core$_N$: Semantic Class$_N$
<M-value>
1524
Surface slot$_{11}$
Surface slot$_{KM}$
S-value$_{K1}$
Core$_{K1}$: Semantic Class$_{K1}$
<M-value>
1530
S-value$_{KM}$
Core$_{KM}$: Semantic Class$_{KM}$
<M-value>
1532

Figure 15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#NormalSentence
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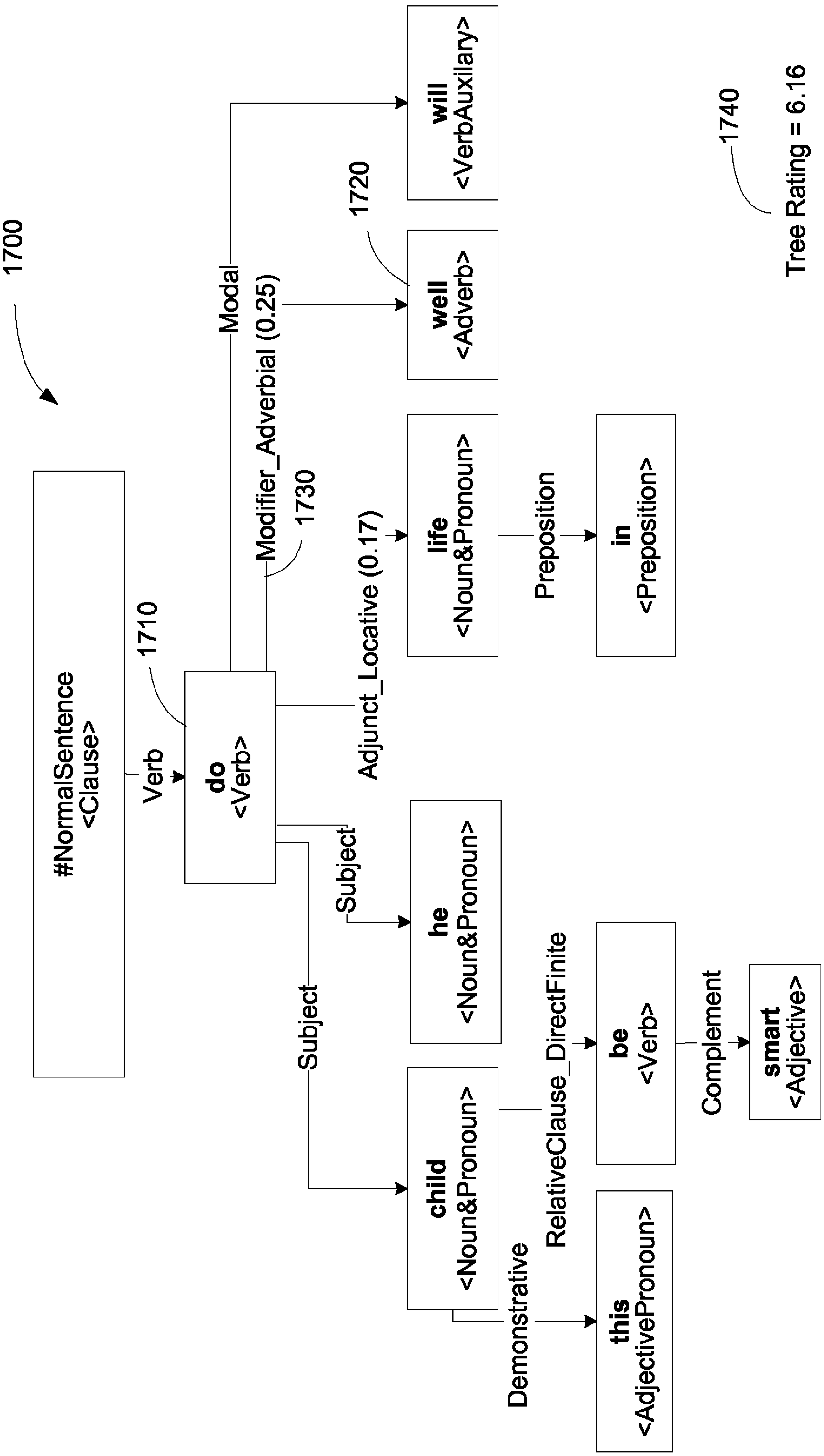
Verb
do
<Verb>
Modal
will
<VerbAuxilary>
Modifier_Adverbial
well
<Adverb>
Adjunct_Locative
life
<Noun&Pronoun>
Preposition
in
<Preposition>
Subject
he
<Noun&Pronoun>
core
be
<Verb>
Complement
smart
<Adjective>
Surface slot
RelativeClause_DirectFinite
grammatical value
Subject
child
<Noun&Pronoun>
Demonstrative
this
<AdjectivePronoun>

Figure 16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#NormalSentence
<Clause>
Verb
1710
do
<Verb>
Modal
will
<VerbAuxilary>
Modifier_Adverbial (0.25)
1730
well
<Adverb>
1720
Adjunct_Locative (0.17)
life
<Noun&Pronoun>
Preposition
in
<Preposition>
Subject
he
<Noun&Pronoun>
Subject
child
<Noun&Pronoun>
RelativeClause_DirectFinite
be
<Verb>
Complement
smart
<Adjective>
Demonstrative
this
<AdjectivePronoun>
1740
Tree Rating = 6.16

Figure 17

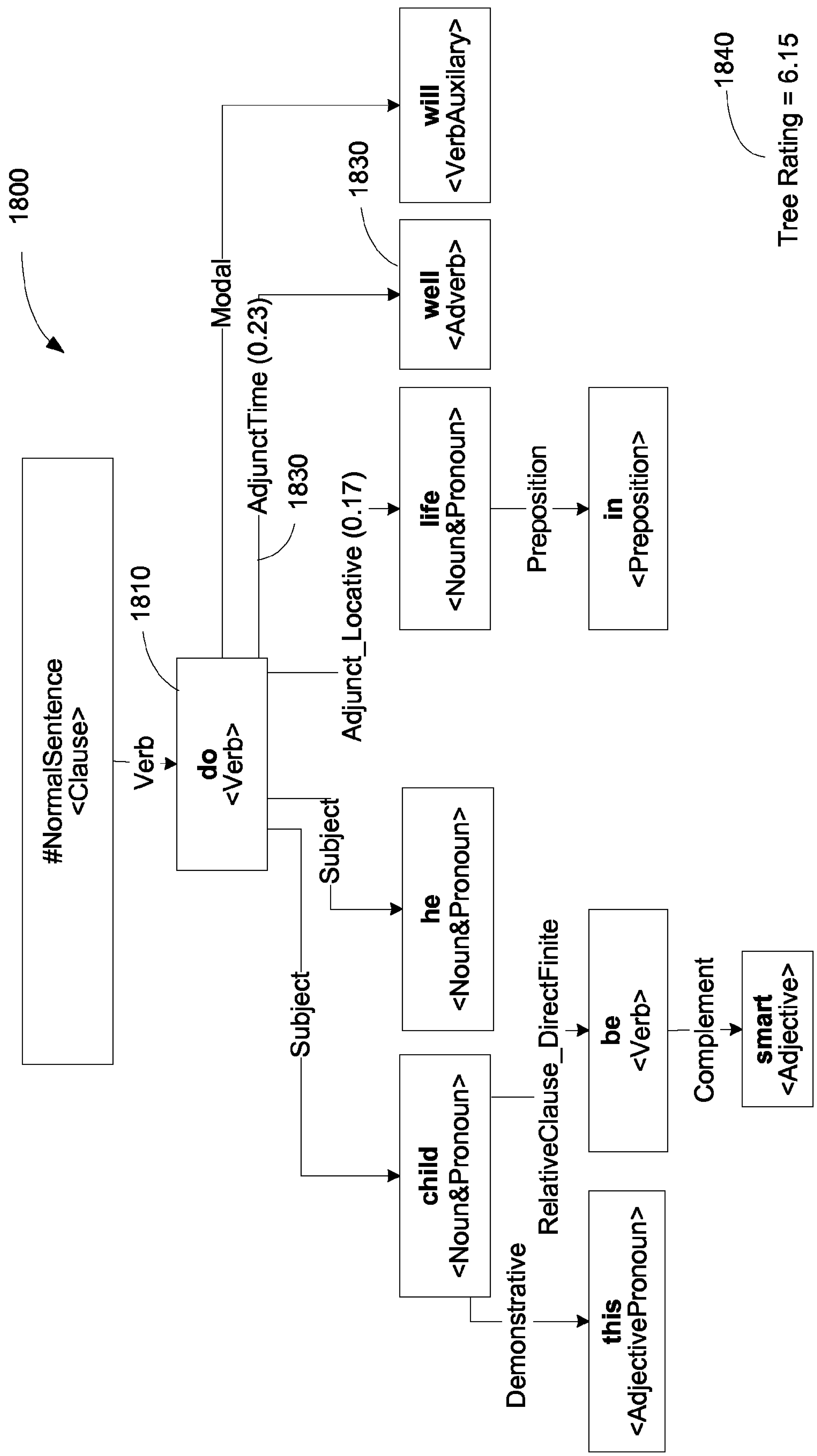
1800
#NormalSentence
<Clause>
Verb
1810
do
<Verb>
Modal
AdjunctTime (0.23)
1830
Adjunct_Locative (0.17)
Subject
Subject
will
<VerbAuxilary>
well
<Adverb>
1830
life
<Noun&Pronoun>
Preposition
in
<Preposition>
he
<Noun&Pronoun>
child
<Noun&Pronoun>
RelativeClause_DirectFinite
be
<Verb>
Complement
smart
<Adjective>
Demonstrative
this
<AdjectivePronoun>
1840
Tree Rating = 6.15

Figure 18

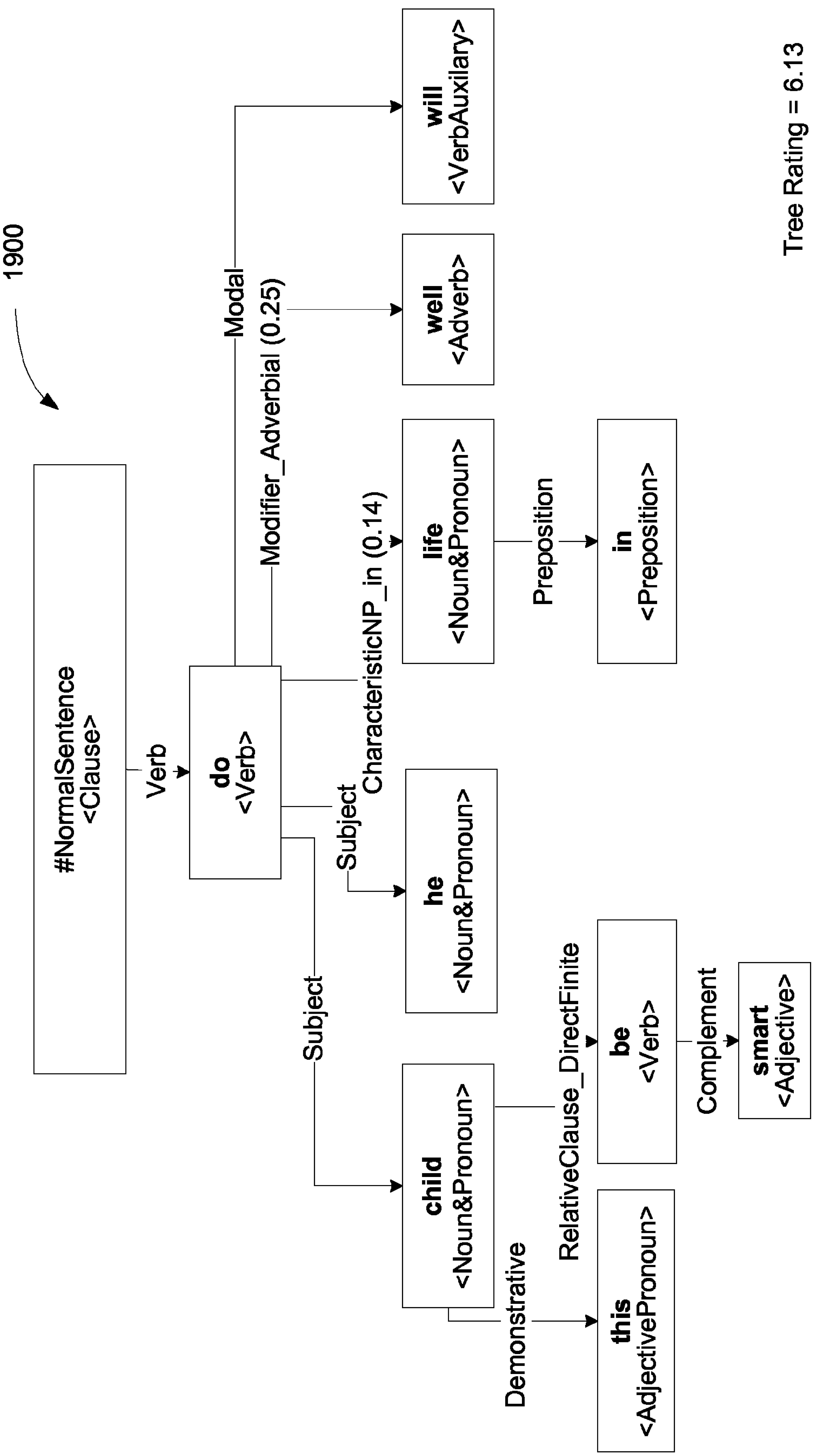
1900
#NormalSentence
<Clause>
Verb
do
<Verb>
Modal
will
<VerbAuxilary>
Modifier_Adverbial (0.25)
well
<Adverb>
CharacteristicNP_in (0.14)
life
<Noun&Pronoun>
Preposition
in
<Preposition>
Subject
he
<Noun&Pronoun>
Subject
child
<Noun&Pronoun>
RelativeClause_DirectFinite
be
<Verb>
Complement
smart
<Adjective>
Demonstrative
this
<AdjectivePronoun>
Tree Rating = 6.13

Figure 19

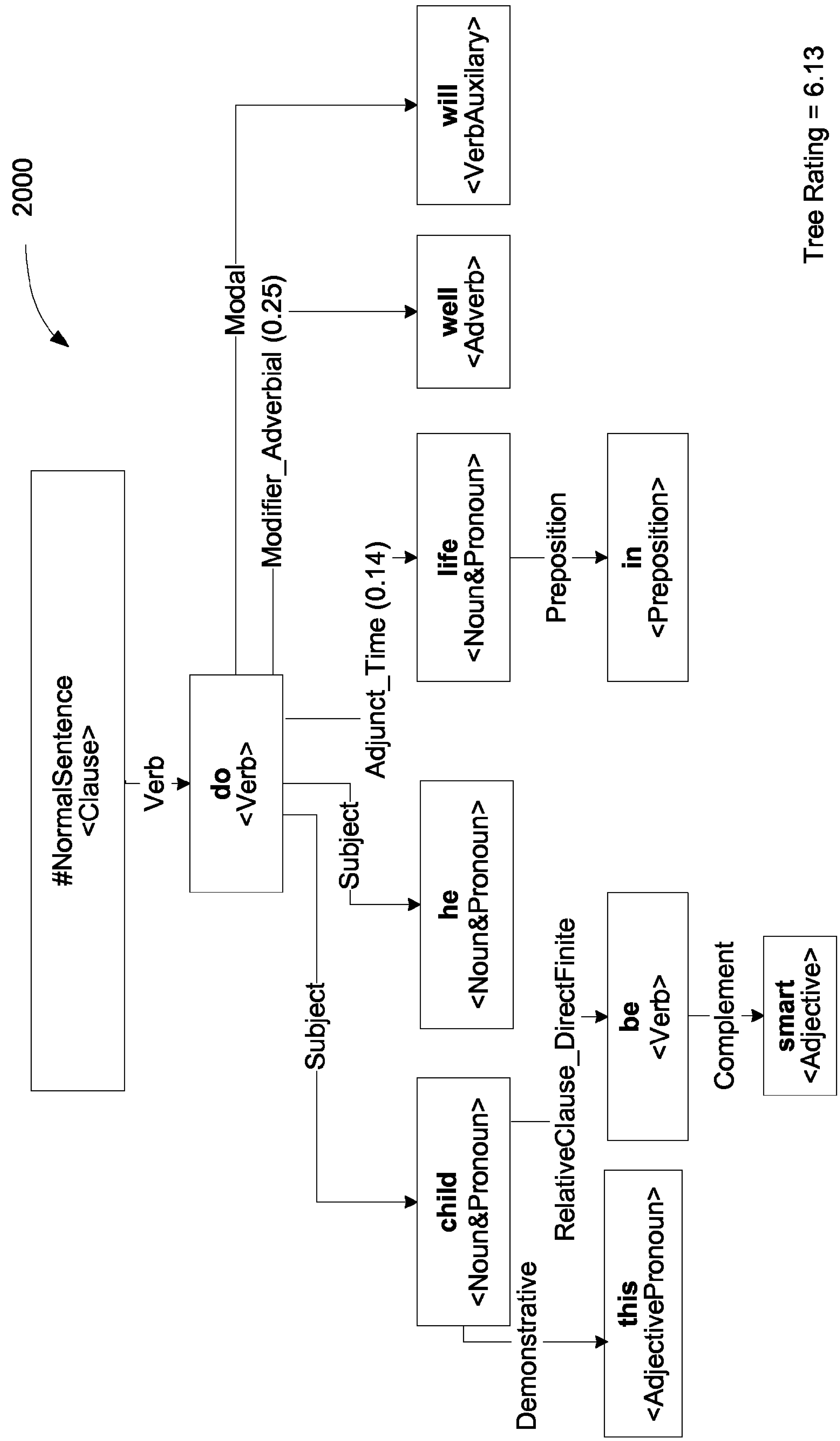
2000
#NormalSentence
<Clause>
Verb
do
<Verb>
Modal
will
<VerbAuxilary>
Modifier_Adverbial (0.25)
well
<Adverb>
Adjunct_Time (0.14)
life
<Noun&Pronoun>
Preposition
in
<Preposition>
Subject
he
<Noun&Pronoun>
Subject
child
<Noun&Pronoun>
RelativeClause_DirectFinite
be
<Verb>
Complement
smart
<Adjective>
Demonstrative
this
<AdjectivePronoun>
Tree Rating = 6.13

Figure 20

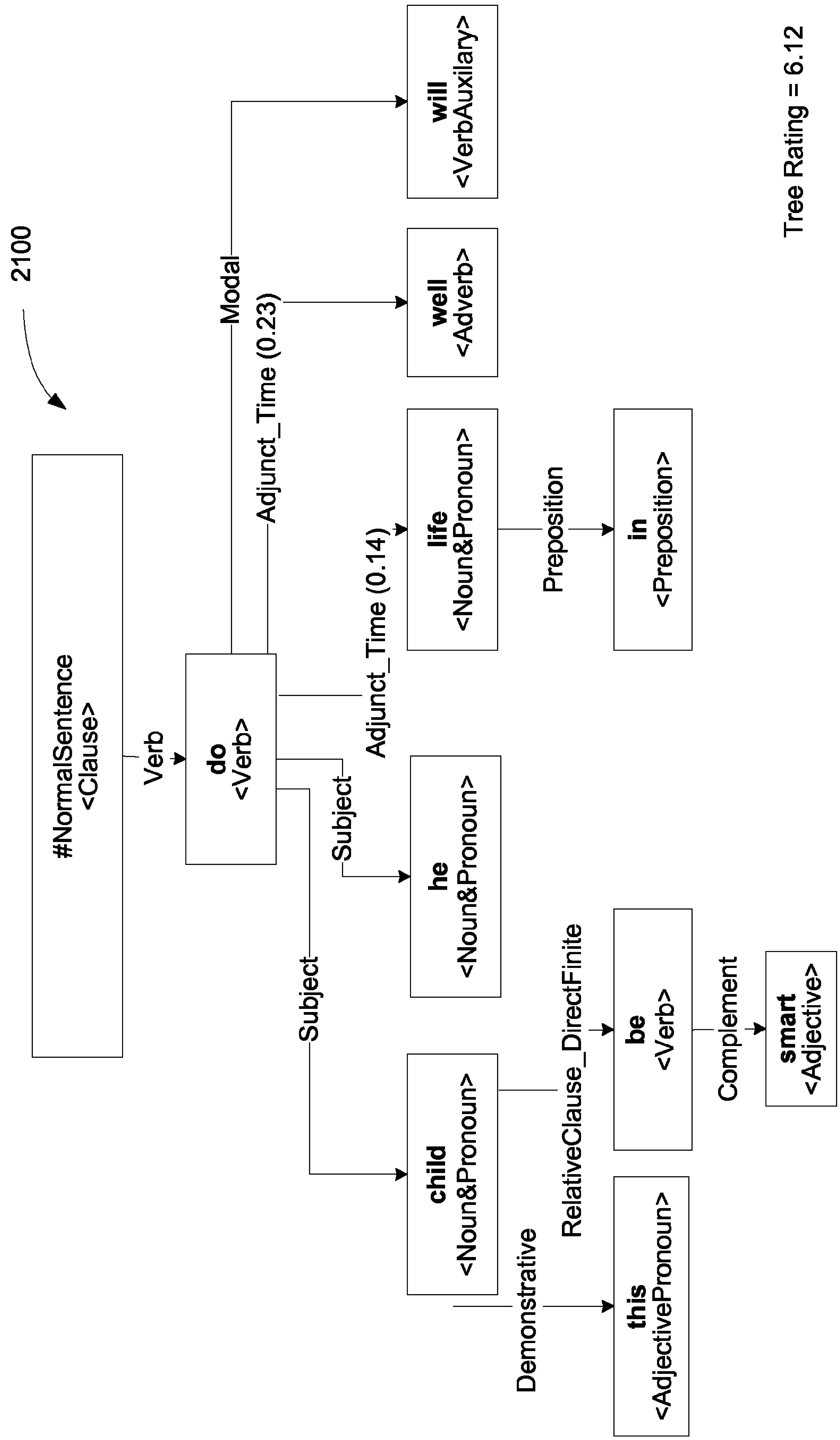
2100
#NormalSentence
<Clause>
Verb
do
<Verb>
Modal
will
<VerbAuxilary>
Adjunct_Time (0.23)
well
<Adverb>
Adjunct_Time (0.14)
life
<Noun&Pronoun>
Preposition
in
<Preposition>
Subject
he
<Noun&Pronoun>
Subject
child
<Noun&Pronoun>
RelativeClause_DirectFinite
be
<Verb>
Complement
smart
<Adjective>
Demonstrative
this
<AdjectivePronoun>
Tree Rating = 6.12

Figure 21

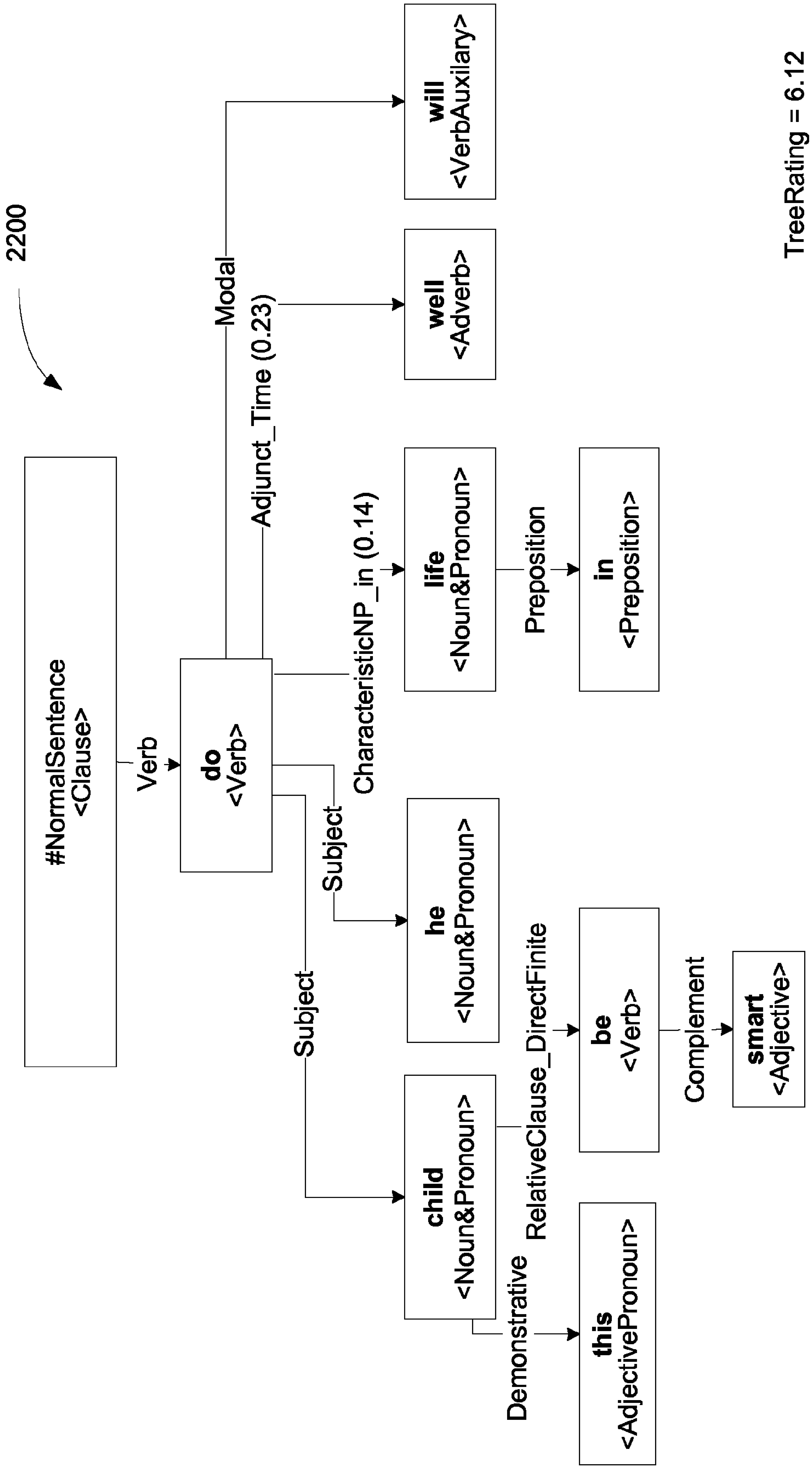
2200
#NormalSentence
<Clause>
Verb
do
<Verb>
Modal
will
<VerbAuxilary>
Adjunct_Time (0.23)
well
<Adverb>
CharacteristicNP_in (0.14)
life
<Noun&Pronoun>
Preposition
in
<Preposition>
Subject
he
<Noun&Pronoun>
Subject
child
<Noun&Pronoun>
RelativeClause_DirectFinite
be
<Verb>
Complement
smart
<Adjective>
Demonstrative
this
<AdjectivePronoun>
TreeRating = 6.12

Figure 22

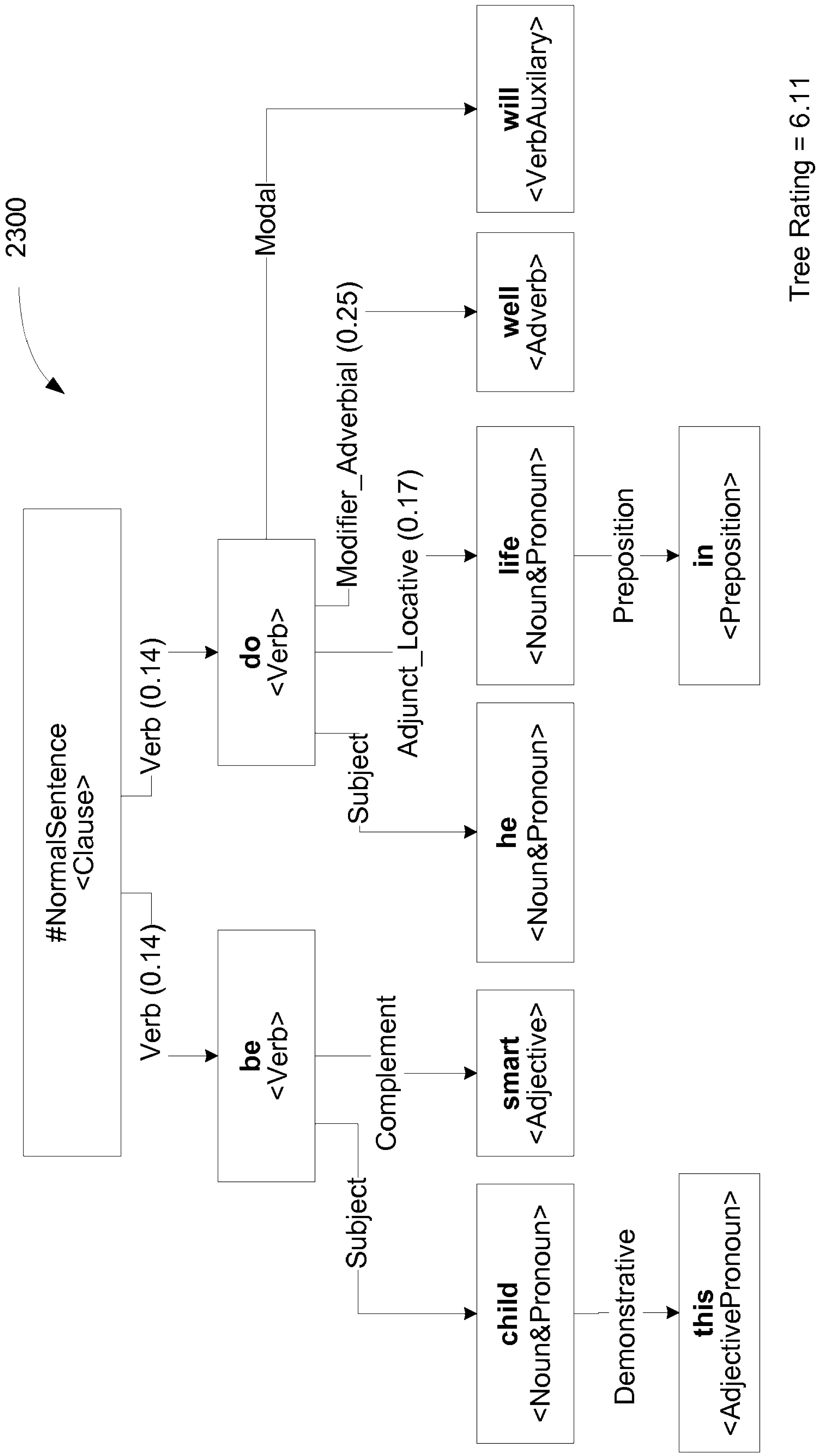
2300
#NormalSentence
<Clause>
Verb (0.14)
Verb (0.14)
do
<Verb>
be
<Verb>
Modal
Modifier_Adverbial (0.25)
Adjunct_Locative (0.17)
Subject
Complement
Subject
will
<VerbAuxilary>
well
<Adverb>
life
<Noun&Pronoun>
he
<Noun&Pronoun>
smart
<Adjective>
child
<Noun&Pronoun>
Preposition
Demonstrative
in
<Preposition>
this
<AdjectivePronoun>
Tree Rating = 6.11

Figure 23

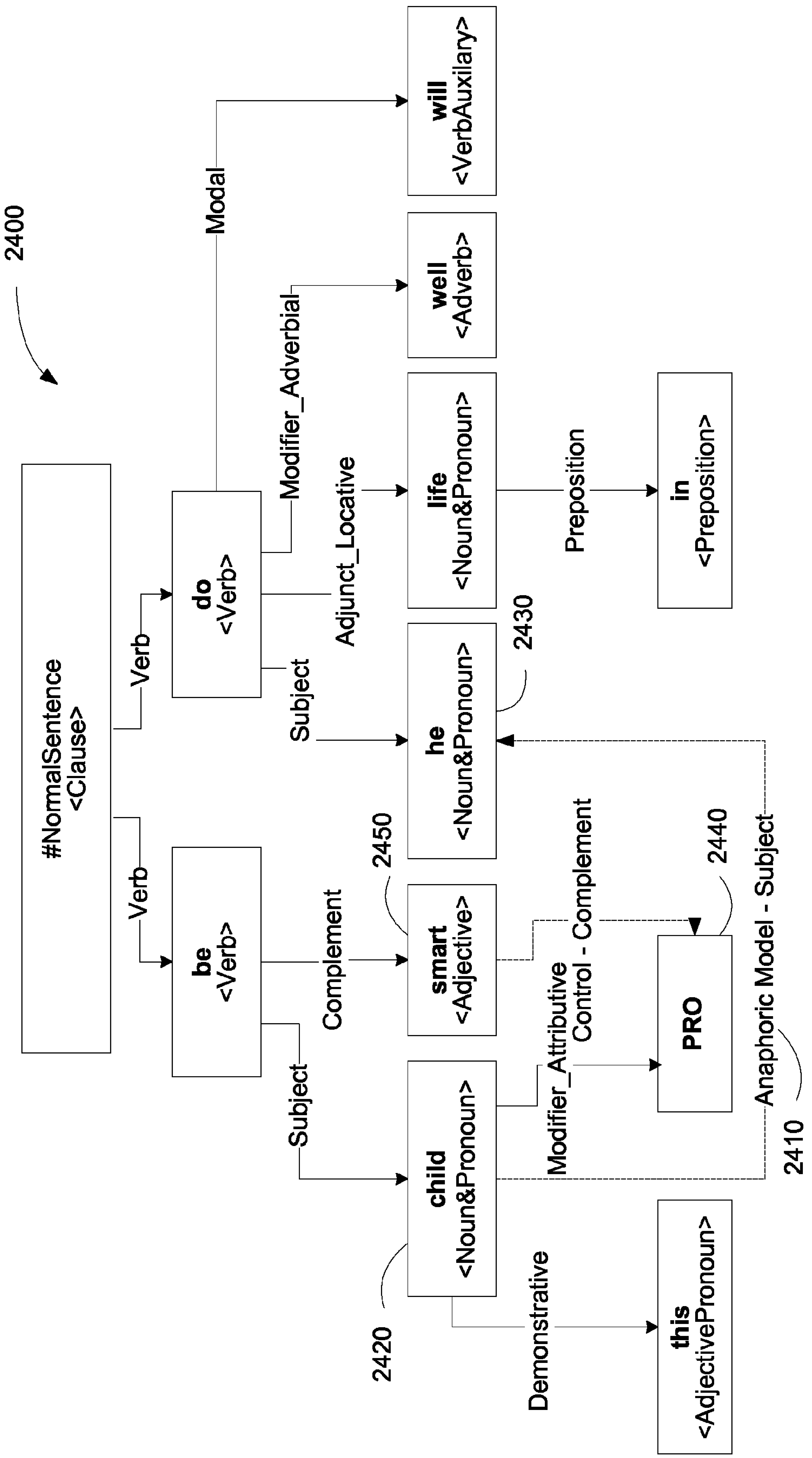
2400
#NormalSentence
<Clause>
Verb
Verb
be
<Verb>
do
<Verb>
Modal
will
<VerbAuxilary>
Modifier_Adverbial
well
<Adverb>
Adjunct_Locative
life
<Noun&Pronoun>
Preposition
in
<Preposition>
Subject
he
<Noun&Pronoun>
2430
Complement
smart
<Adjective>
2450
Control - Complement
PRO
2440
Anaphoric Model - Subject
2410
Subject
child
<Noun&Pronoun>
Modifier_Attributive
2420
Demonstrative
this
<AdjectivePronoun>

Figure 24

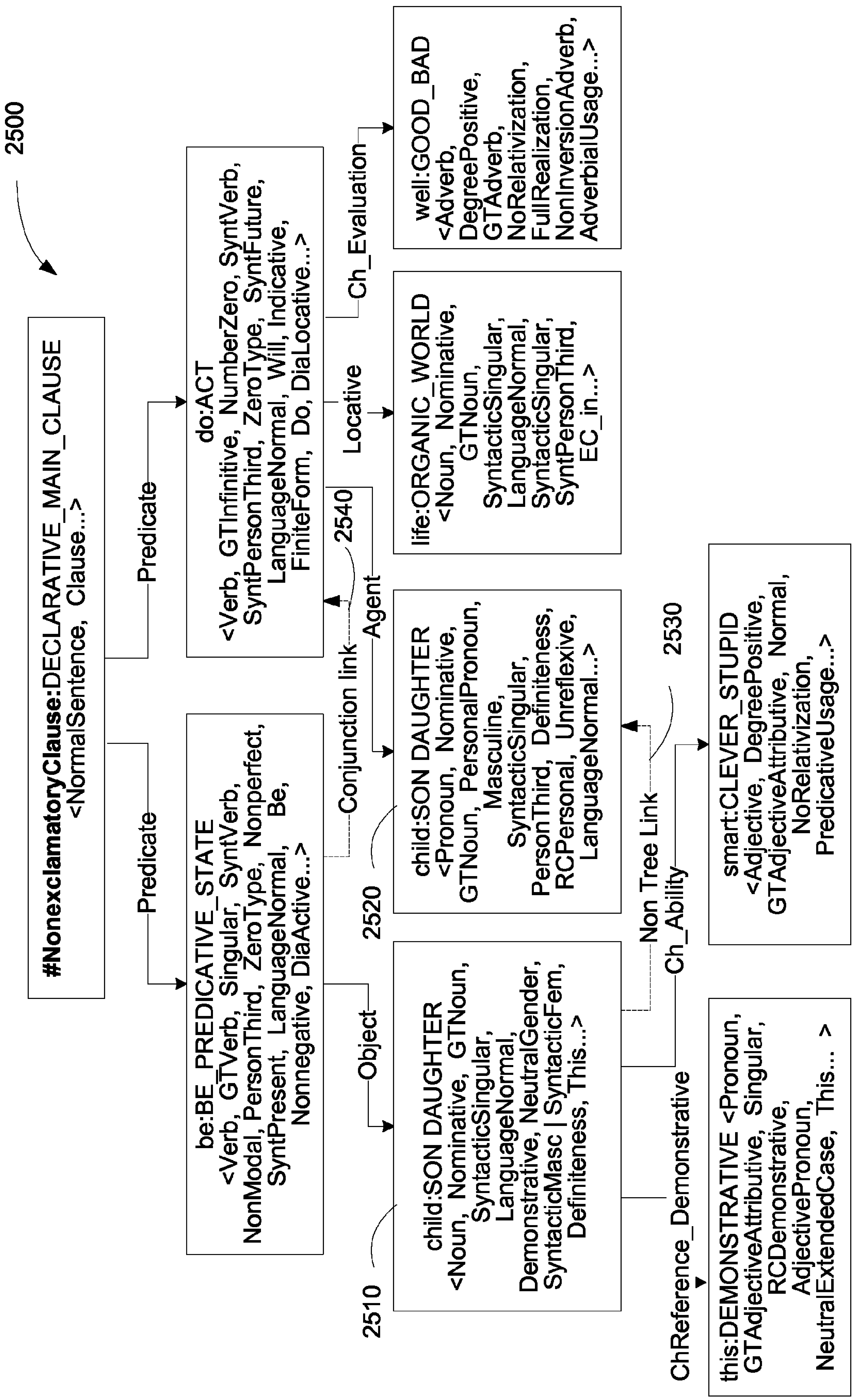
2500
#NonexclamatoryClause:DECLARATIVE_MAIN_CLAUSE <NormalSentence, Clause...>
Predicate
Predicate
be:BE_PREDICATIVE_STATE <Verb, GTVerb, Singular, SyntVerb, NonModal, PersonThird, ZeroType, Nonperfect, SyntPresent, LanguageNormal, Be, Nonnegative, DiaActive...>
do:ACT <Verb, GTInfinitive, NumberZero, SyntVerb, SyntPersonThird, ZeroType, SyntFuture, LanguageNormal, Will, Indicative, FiniteForm, Do, DiaLocative...>
Conjunction link
2540
Agent
Locative
Ch_Evaluation
Object
child:SON DAUGHTER <Noun, Nominative, GTNoun, SyntacticSingular, LanguageNormal, Demonstrative, NeutralGender, SyntacticMasc | SyntacticFem, Definiteness, This...>
child:SON DAUGHTER <Pronoun, Nominative, GTNoun, PersonalPronoun, Masculine, SyntacticSingular, PersonThird, Definiteness, RCPersonal, Unreflexive, LanguageNormal...>
life:ORGANIC_WORLD <Noun, Nominative, GTNoun, SyntacticSingular, LanguageNormal, SyntacticSingular, SyntPersonThird, EC_in...>
well:GOOD_BAD <Adverb, DegreePositive, GTAdverb, NoRelativization, FullRealization, NonInversionAdverb, AdverbialUsage...>
2510
2520
2530
Non Tree Link
Ch_Ability
ChReference_Demonstrative
this:DEMONSTRATIVE <Pronoun, GTAdjectiveAttributive, Singular, RCDemonstrative, AdjectivePronoun, NeutralExtendedCase, This... >
smart:CLEVER_STUPID <Adjective, DegreePositive, GTAdjectiveAttributive, Normal, NoRelativization, PredicativeUsage...>

Figure 25

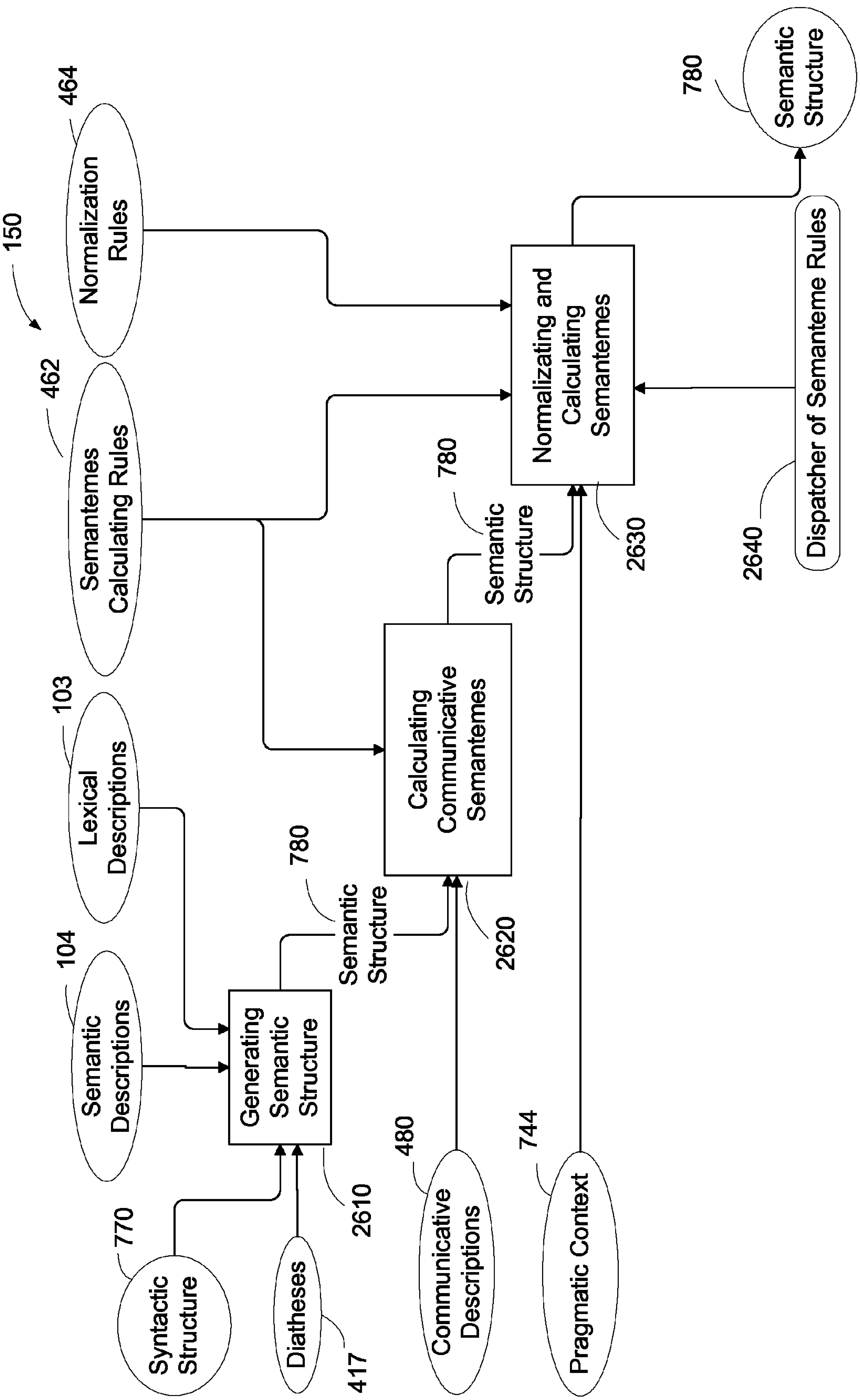
150
464
Normalization Rules
462
Semantemes Calculating Rules
103
Lexical Descriptions
104
Semantic Descriptions
770
Syntactic Structure
Diatheses
417
Generating Semantic Structure
2610
780
Semantic Structure
Calculating Communicative Semantemes
2620
480
Communicative Descriptions
744
Pragmatic Context
780
Semantic Structure
Normalizating and Calculating Semantemes
2630
2640
Dispatcher of Semanteme Rules
780
Semantic Structure

Figure 26

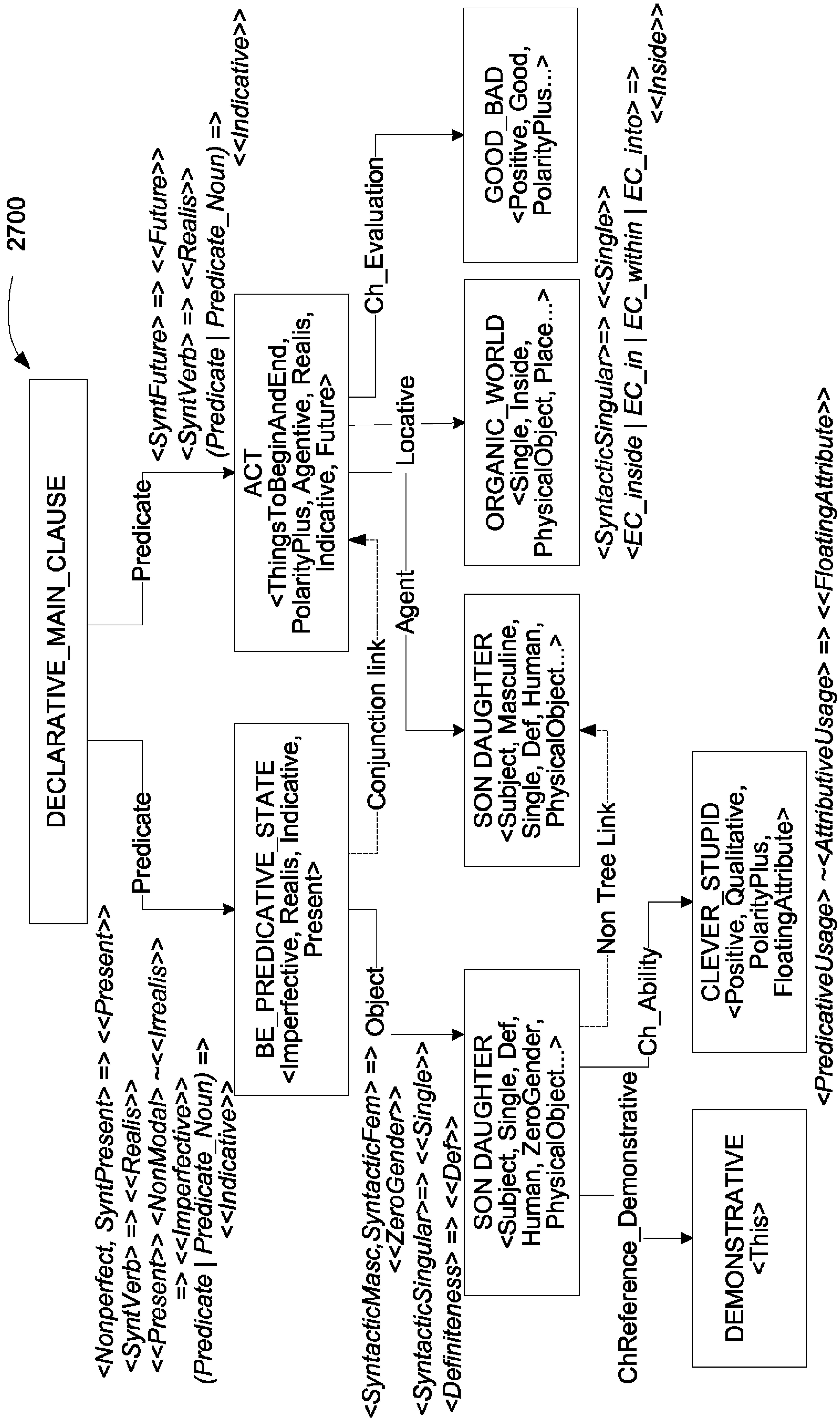
2700
DECLARATIVE_MAIN_CLAUSE
Predicate
Predicate
BE_PREDICATIVE_STATE <Imperfective, Realis, Indicative, Present>
ACT <ThingsToBeginAndEnd, PolarityPlus, Agentive, Realis, Indicative, Future>
<Nonperfect, SyntPresent> => <<Present>>
<SyntVerb> => <<Realis>>
<<Present>> <NonModal> ~<<Irrealis>>
=> <<Imperfective>>
(Predicate | Predicate_Noun) =>
<<Indicative>>
<SyntFuture> => <<Future>>
<SyntVerb> => <<Realis>>
(Predicate | Predicate_Noun) =>
<<Indicative>>
Conjunction link
Object
Agent
Locative
Ch_Evaluation
<SyntacticMasc,SyntacticFem> =>
<<ZeroGender>>
<SyntacticSingular>=> <<Single>>
<Definiteness> => <<Def>>
SON DAUGHTER <Subject, Single, Def, Human, ZeroGender, PhysicalObject...>
SON DAUGHTER <Subject, Masculine, Single, Def, Human, PhysicalObject...>
ORGANIC_WORLD <Single, Inside, PhysicalObject, Place...>
GOOD_BAD <Positive, Good, PolarityPlus...>
Non Tree Link
Ch_Ability
ChReference_Demonstrative
DEMONSTRATIVE <This>
CLEVER_STUPID <Positive, Qualitative, PolarityPlus, FloatingAttribute>
<SyntacticSingular>=> <<Single>>
<EC_inside | EC_in | EC_within | EC_into> =>
<<Inside>>
<PredicativeUsage> ~<AttributiveUsage> => <<FloatingAttribute>>

Figure 27

METHOD AND SYSTEM FOR ANALYZING AND TRANSLATING VARIOUS LANGUAGES WITH USE OF SEMANTIC HIERARCHY

CROSS-REFERENCE TO RELATED APPLICATIONS

For purposes of the USPTO extra-statutory requirements, the present application constitutes a continuation-in-part of U.S. patent application Ser. No. 11/548,214 that was filed on 10 Oct. 2006 now U.S. Pat. No. 8,078,450, which is currently, or is an application of which a currently co-pending application is entitled to the benefit of the filing date.

The United States Patent Office (USPTO) has published a notice effectively stating that the USPTO's computer programs require that patent applicants reference both a serial number and indicate whether an application is a continuation or continuation-in-part. See Stephen G. Kunin, Benefit of Prior-Filed Application, USPTO Official Gazette 18 Mar. 2003. The present Applicant Entity (hereinafter "Applicant") has provided above a specific reference to the application(s) from which priority is being claimed as recited by statute. Applicant understands that the statute is unambiguous in its specific reference language and does not require either a serial number or any characterization, such as "continuation" or "continuation-in-part," for claiming priority to U.S. patent applications. Notwithstanding the foregoing, Applicant understands that the USPTO's computer programs have certain data entry requirements, and hence Applicant is designating the present application as a continuation-in-part of its parent applications as set forth above, but expressly points out that such designations are not to be construed in any way as any type of commentary and/or admission as to whether or not the present application contains any new matter in addition to the matter of its parent application(s).

All subject matter of the Related Applications and of any and all parent, grandparent, great-grandparent, etc. applications of the Related Applications is incorporated herein by reference to the extent such subject matter is not inconsistent herewith.

BACKGROUND OF THE INVENTION

1. Field of the Invention

Embodiments of the invention generally relate to automated recognition of the meanings of natural-language sentences and language translation.

2. Description of the Related Art

The acquired ability to understand, speak, and write one or more languages is an integral part of human development to interact and communicate within a society. Various language analysis approaches have been used to dissect a given language, analyze its linguistic structure in order to understand the meanings of a word, a sentence in the given language, extract information from the word, the sentence, and, if necessary, translate into another language.

Prior language analysis systems with a semantic component usually are created for a very restricted area of application, for example, medical diagnostics or ticket sales/reservation. In these analysis systems, only simple sentence patterns with restricted syntax and semantics are used. In addition, syntactic descriptions in general are not linked with the semantic descriptions. Other machine translation systems, both rule-based and statistics-based, concentrate on proper transfer of language information and usually make no use of any full-fledged intermediary data structures which explicate the meaning of the sentence being translated.

Certain theoretical concepts, such as Parallel Correspondence Model, propose the idea of uniting and linking syntactical information with semantic information together. For example, the most developed of these theoretical concepts are Generalized Phrase Structure Grammar (GPSG), Head-Driven Phrase Structure Grammar (HPSG), and Lexical Function Grammar. However, most of them have not been put into usable algorithms for language analysis.

As a result, even though various models have been proposed, most of them perform poorly in analyzing complete sentences experimentally and do not have any noteworthy industrial application. In addition, complex sentences are often very long and contain various punctuation and symbols such that prior art parsers, language analysis programs, or machine translation systems often have difficulty returning a complete parse or translation on sentences beyond a certain level of complexity. It is especially true for complex texts, such as those found in technical texts, documentation, internet articles, journals, and the likes.

Further, the decision to remove ambiguous results or defer such actions during different stages of the language analysis and/or machine translation often complicates the analysis and translation itself, leading to a very low percentage of successful cases. Attempts to successfully analyze one language sentence and synthesize into another language all have the drawbacks of being very time-consuming and/or compatible or applicable only to specific languages.

Thus, there exists a need to analyze a sentence of a given language and construct a language independent structure/description so as to understand the meanings of the sentence and/or translate into another language.

SUMMARY

Embodiments of the invention generally relate to methods, computer-readable media, devices and systems to analyze a sentence or an expression in a language. In one embodiment, a sentence from a given language is analyzed by applying the methods, rules, and algorithms provided herein, and a language independent semantic structure for a sentence from a given language is generated. In another embodiment, a first sentence from a first language is translated into a second sentence in a second language using the language independent semantic structure.

In one aspect, a method of analyzing a sentence or an expression of a language includes performing a lexical analysis of the sentence, performing a lexical-morphological analysis of the sentence, and building a lexical-morphological structure of the sentence. The method further includes performing a rough syntactic analysis on the lexical-morphological structure of the sentence, generating a graph of generalized constituents from the lexical-morphological structure of the sentence, performing a precise syntactic analysis on the basis of the graph of the generalized constituents, and generating one or more syntactic trees from the graph of the generalized constituents. Then non-tree links are established for the best syntactic tree, and a best syntactic structure is obtained. A language-independent semantic structure for the sentence of the language is then generated after performing a semantic analysis on the best syntactic structure.

In another aspect, a method of analyzing a sentence or expression in a source language includes performing a lexical analysis of the sentence in the source language, performing a lexical-morphological analysis on the each element of the sentence, and building a lexical-morphological structure for the whole sentence, performing a rough syntactic analysis on the lexical-morphological structure of the sentence using one or more lexical descriptions, one or more semantic descriptions, and one or more syntactic descriptions, building a set of all possible constituents for each element of the sentence, and building a graph of the generalized constituents bottom up from the lexical-morphological structure of the sentence.

The method further includes performing a precise syntactic analysis on the graph of the generalized constituents and generating a graph of precise constituents, generating one or more syntactic trees from the graph of the precise constituents, establishing non-tree links on the one or more syntactic trees, generating one or more syntactic structure variants and selecting a best syntactic structure from the one or more syntactic structure variants, performing a semantic analysis on the best syntactic structure of the sentence, and generating a language-independent semantic structure for the sentence of the language. The method further includes performing filtering of the constituents prior to and after building the graph of the generalized constituents. In addition, building the graph of the generalized constituents may include performing coordination processing and ellipsis restoration. Further, performing the precise syntactic analysis may include generating a graph of precise constituents and rating the one or more precise constituents based on a plurality of rating scores independently obtained and calculated. The rating scores includes, but not limited to, the rating scores of one or more lexical meanings for each element of the sentence, the rating scores of one or more individual syntactic constructions (e.g., idioms, collocations, etc.) for each element of the sentence, the rating scores of the degree of correspondence of the precise constituents to their semantic descriptions, and the rating scores of the linear order. Then, the rating scores are used to generate one or more syntactic trees as hypotheses about the overall syntactic structure of the sentence. One or more best syntactic trees with the highest rating score are selected. The precise syntactic analysis may further include establishing non-tree links on the one or more best syntactic trees to generate one or more syntactic structures with non-tree links and selecting a best syntactic structure with established non-tree links.

In one embodiment, a computer-readable medium is provided, comprising instructions for causing a computing system to carry out steps including performing a lexical analysis of the sentence in the source language, performing a lexical-morphological analysis on the each element of the sentence and building a lexical-morphological structure for the whole sentence, performing a rough syntactic analysis on the lexical-morphological structure of the sentence and generating a graph of generalized constituents from the lexical-morphological structure of the sentence, performing a precise syntactic analysis on the graph of the generalized constituents and generating one or more syntactic structures for the sentence from the graph of the generalized constituents, performing a semantic analysis on the syntactic structures of the sentence and generating a language-independent semantic structure for the sentence of the language.

In still another embodiment, the invention provides a device and/or a computer system adapted to analyze a sentence of a language. The computer system may include a lexical-morphological analyzer, a rough syntactic analyzer, a precise syntactic analyzer, and a semantic analyzer. The lexical-morphological analyzer is adapted to perform a lexical analysis and a lexical-morphological analysis on each element of the sentence and generating a lexical-morphological structure of the sentence. The rough syntactic analyzer is adapted to perform a rough syntactic analysis on the lexical-morphological structure of the sentence and generate a graph of generalized constituents from the lexical-morphological structure of the sentence. The precise syntactic analyzer is adapted to perform a precise syntactic analysis on the graph of the generalized constituents and generate a syntactic structure of the sentence from the graph of the generalized constituents. The semantic analyzer is adapted to perform a semantic analysis on the syntactic structure of the sentence and generate a language-independent semantic structure for the sentence of the language.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

FIG. **1** is a flow diagram of a method according to one or more embodiments of the invention.

FIG. **2** is a diagram illustrating language descriptions according to one exemplary embodiment of the invention.

FIG. **3** is a diagram illustrating morphological descriptions according to one exemplary embodiment of the invention.

FIG. **4** is a diagram illustrating syntactic descriptions according to one exemplary embodiment of the invention.

FIG. **5** is a diagram illustrating semantic descriptions according to one exemplary embodiment of the invention.

FIG. **6** is a diagram illustrating lexical descriptions according to one exemplary embodiment of the invention.

FIG. **7** is a process flow diagram according to one or more embodiments of the invention.

FIG. **8** is an exemplary lexical structure for an exemplary sentence "This child is smart, he'll do well in life." according to one embodiment of the invention.

FIG. **9** is a lexical-morphological structure for an exemplary sentence according to one embodiment of the invention.

FIG. **10** is the result of generalization of grammatical values for the lexemes identified in the exemplary sentence according to one embodiment of the invention.

FIG. **11** is a process flow diagram illustrating rough syntactic analyses according to one or more embodiments of the invention.

FIG. **12** is an exemplary graph of generalized constituents for the sentence "This child is smart, he'll do well in life." according to one embodiment of the invention.

FIG. **13** is an exemplary dispatching rule according to one embodiment of the invention.

FIG. **14** is a process flow diagram illustrating precise syntactic analyses according to one or more embodiments of the invention.

FIG. **15** is an exemplary schematic representation of a syntactic tree according to one embodiment of the invention.

FIG. **16** is an exemplary syntactic tree of the above mentioned sentence "This child is smart, he'll do well in life."

FIG. **17** shows a modified syntactic tree shown on FIG. **16**.

FIG. 18 is another syntactic tree for the exemplary sentence extracted from the graph of generalized constituents from FIG. 12.

FIG. 19 is still another syntactic tree for the exemplary sentence extracted from the graph of generalized constituents from FIG. 12.

FIG. 20 is still another syntactic tree for the exemplary sentence extracted from the graph of generalized constituents from FIG. 12.

FIG. 21 is still another syntactic tree for the exemplary sentence extracted from the graph of generalized constituents from FIG. 12.

FIG. 22 is still another syntactic tree for the exemplary sentence extracted from the graph of generalized constituents from FIG. 12.

FIG. 23 is a best syntactic tree for the exemplary sentence extracted from the graph of generalized constituents from FIG. 12.

FIG. 24 is an exemplary best syntactic structure for the exemplary sentence with non-tree links generated on the basis of the syntactic tree which is shown on FIG. 23.

FIG. 25 is one example of the best syntactic structure with semantic parents of lexical meanings and their grammemes generated for the exemplary sentence.

FIG. 26 is a process flow diagram illustrating semantic analyses according to one or more embodiments of the invention.

FIG. 27 is an exemplary semantic structure with semantemes and exemplary analysis rules according to one or more embodiments of the invention.

DETAILED DESCRIPTION

Embodiments of the invention provide methods, computer-readable media, and language analysis computer systems to efficiently and completely generate surface syntactical structures for a given input/source language and transition into language-independent, universal semantic concepts and structures which are not limited by the syntax and other language barriers of the input language. Using exhaustive linguistic descriptions, language and semantic models and a corresponding method were developed to recognize and analyze the meanings of sentences of a given language through reliable handling of syntactical and semantic ambiguities which may appear during the transition. Unlike other systems where semantic structures are built as the final or interim result of language processing, embodiments of the invention achieve its aims by maximal use of linguistic knowledge to generate the resulting semantic structure which contains a large amount of various data information about the meaning of a sentence.

One feature according to embodiments of the invention is the integral use of language descriptions to analyze initial text sentences and join syntactical and semantic foundations into common concept structures. This approach is provided to analyze semantics at the earliest stages of syntactical analysis. Unlike prior research in this field, an efficient technology is provided herein to transition from surface syntactical structures in different languages into language-independent semantic structures and does not limit the input language's syntax. Thus, a semantic model is developed to be suitable for building the semantic structures and reliably handle syntactical and semantic ambiguities present during the transition. Since linguistic knowledge is taken into consideration to a greater extent than any known art, all the information and meanings conveyed by a given sentence in a language are truly and faithfully represented by the resulting semantic structure generated herein.

In addition, the natural language descriptions used herein attempt to cover all of language phenomena manifested in written discourse as completely and exhaustively as possible. In one aspect, the linguistic descriptions and algorithms used herein may be employed as exhaustively and comprehensively as possible to make it possible to construct a most probable and most suitable semantic structure for any written sentences from any source languages within an acceptable period of time.

Embodiments of the invention include methods and means for constructing a model of any natural language, which includes creation of the required language descriptions as described herein; for describing a language-independent semantic structure which conveys the meanings of source sentences in any natural language; for transforming sentences in a natural language into their semantic structures, among others. Computer readable media, language analysis computer systems, instructions, algorithms, and means for carrying out various methods are also provided herein. An environment for a user to monitor various analysis processes is also provided herein. For example, embodiments of the invention may include a method being implemented in various forms, formats, or algorithms and adapted to be operated on a computer-readable medium, a computer program, or a device for analyzing a sentence of a source language and generating a language-independent semantic structure.

FIG. 1 illustrates a method 100 for transforming a sentence from a source language into its semantic structure according to an exemplary embodiment of the invention. The method 100 for analyzing a sentence of a source/input language includes using linguistic descriptions adapted to perform various analyses. The linguistic descriptions may include morphological descriptions 101, syntactic descriptions 102, lexical descriptions 103, and semantic descriptions 104.

Initially, a lexical analysis 110 is performed on the sentence in the source/input language. A lexical-morphological analysis 120 which utilizes the morphological descriptions 101 and the lexical descriptions 103 is also performed on the sentence to generate a lexical morphological structure of the sentence. In addition, a syntactic analysis including a rough syntactic analysis 130 and a precise syntactic analysis 140 is performed to generate a syntactic structure of the sentence. Performing the rough syntactic analysis and the precise syntactic analysis may require the use of the syntactical descriptions 102, the lexical descriptions 103, and the semantic descriptions 104. The precise syntactic analysis may be performed repeatedly if the syntactic structure is not successfully built.

Then, a semantic analysis 150 is performed to transition the syntactic structure of the source sentence in the natural language into a language-independent semantic structure. The resulting semantic structure fully conveys the meaning of the source sentence in the source natural language but represents the source sentence in a language-independent form.

FIG. 2 illustrates language descriptions 210 including morphological descriptions 101, lexical descriptions 103, syntactic descriptions 102, and semantic descriptions 104, and their relationship thereof. Among them, the morphological descriptions 101, the lexical descriptions 103, and the syntactic descriptions 102 are language-specific. Each of these language descriptions 210 can be created for each source language, and taken together, they represent a model of the source language. The semantic descriptions **104**, however, are language-independent and are used to describe language-independent semantic features of various languages and to construct language-independent semantic structures.

As shown in FIG. **2**, the morphological descriptions **101**, the lexical descriptions **103**, the syntactic descriptions **102**, and the semantic descriptions **104** are related. Lexical descriptions **104** and morphological descriptions **101** are related by a link **221** because a specified lexical meaning in the lexical description **230** may have a morphological model represented as one or more grammatical values for the specified lexical meaning. For example, one or more grammatical values can be represented by different sets of grammemes in a grammatical system of the morphological descriptions **101**.

In addition, as shown by a link **222**, a given lexical meaning in the lexical descriptions **103** may also have one or more surface models corresponding to the syntactic descriptions **102** for the given lexical meaning. As represented by a link **223**, the lexical descriptions **103** can be connected with the semantic descriptions **104**. Therefore, the lexical descriptions **103** and the semantic descriptions **104** may be combined into "lexical-semantic descriptions", such as a lexical-semantic dictionary.

As shown by a link **224**, the syntactic descriptions **240** and the semantic descriptions **104** are also related. For examples, diatheses **417** of the syntactic descriptions **102** can be considered as the "interface" between the language-specific surface models and the language-independent deep models **512** of the semantic description **104**.

FIG. **3** illustrates exemplary morphological descriptions. The components of the morphological descriptions **101** include, but are not limited to, word-inflexion description **310**, grammatical system **320** (e.g., grammemes), and word-formation description **330**, among others. The grammatical system **320** is a set of grammatical categories, such as, "Part of speech", "Case", "Gender", "Number", "Person", "Reflexivity", "Tense", "Aspect", etc., and their meanings, hereafter referred to as "grammemes", including, for example, Adjective, Noun, Verb, etc.; Nominative, Accusative, Genitive, etc.; Feminine, Masculine, Neuter, etc.; and more.

The word-inflexion description **310** describes how the main word form may change according to its case, gender, number, tense, etc. and broadly includes or describes all possible forms for this word. The word-formation **330** describes which new words may be generated involving this word (for example, there are a lot of compound words in German). The grammemes are units of the grammatical systems **320** and, as shown by a link **322** and a link **324** in FIG. **3**, the grammemes can be utilized to build the word-inflexion description **310** and the word-formation description **330**.

According to one aspect of the invention, when establishing syntactic relationships for elements of the source sentence, a constituent model is used. A constituent may include a contiguous group of words in a sentence and behaves as one entity. A constituent has a word at its core and can include child constituents at lower levels. A child constituent is a dependent constituent and may be attached to other constituents (as parent constituents) for building the syntactic descriptions **102** of the source sentence.

FIG. **4** illustrates exemplary syntactic descriptions. The components of the syntactic descriptions **102** may include, but are not limited to, surface models **410**, surface slot descriptions **420**, referential and structural control description **430**, government and agreement description **440**, non-tree syntax description **450**, and analysis rules **460**. The syntactic descriptions **102** are used to construct possible syntactic structures of a source sentence from a given source language, taking into account free linear word order, non-tree syntactic phenomena (e.g., coordination, ellipsis, etc.), referential relationships, and other considerations.

The surface models **410** are represented as aggregates of one or more syntactic forms ("syntforms" **412**) in order to describe possible syntactic structures of sentences as included in the syntactic description **102**. In general, the lexical meaning of a language is linked to their surface (syntactic) models **410**, which represent constituents which are possible when the lexical meaning functions as a "core" and includes a set of surface slots of child elements, a description of the linear order, diatheses, among others.

The surface models **410** as represented by syntforms **412**. Each syntform **412** may include a certain lexical meaning which functions as a "core" and may further include a set of surface slots **415** of its child constituents, a linear order description **416**, diatheses **417**, grammatical values **414**, government and agreement descriptions **440**, communicative descriptions **480**, among others, in relationship to the core of the constituent.

The surface slot descriptions **420** as a part of syntactic descriptions **102** are used to describe the general properties of the surface slots **415** that used in the surface models **410** of various lexical meanings in the source language. The surface slots **415** are used to express syntactic relationships between the constituents of the sentence. Examples of the surface slot **415** may include "subject", "object_direct", "object_indirect", "relative clause", among others.

During the syntactic analysis, the constituent model utilizes a plurality of the surface slots **415** of the child constituents and their linear order descriptions **416** and describes the grammatical values **414** of the possible fillers of these surface slots **415**. The diatheses **417** represent correspondences between the surface slots **415** and deep slots **514** (as shown in FIG. **5**). The diatheses **417** are represented by the link **224** between syntactic descriptions **102** and semantic descriptions **104**. The communicative descriptions **480** describe communicative order in a sentence.

The syntactic forms, syntforms **412**, are a set of the surface slots **415** coupled with the linear order descriptions **416**. One or more constituents possible for a lexical meaning of a word form of a source sentence may be represented by surface syntactic models, such as the surface models **410**. Every constituent is viewed as the realization of the constituent model by means of selecting a corresponding syntform **412**. The selected syntactic forms, the syntforms **412**, are sets of the surface slots **415** with a specified linear order. Every surface slot in a syntform can have grammatical and semantic restrictions on their fillers.

The linear order description **416** is represented as linear order expressions which are built to express a sequence in which various surface slots **415** can occur in the sentence. The linear order expressions may include names of variables, names of surface slots, parenthesis, grammemes, ratings, and the "or" operator, etc. For example, a linear order description for a simple sentence of "Boys play football." may be represented as "Subject Core Object_Direct", where "Subject, Object_Direct" are names of surface slots **415** corresponding to the word order. Fillers of the surface slots **415** indicated by symbols of entities of the sentence are present in the same order for the entities in the linear order expressions.

Different surface slots **415** may be in a strict and/or variable relationship in the syntform **412**. For example, parenthesis may be used to build the linear order expressions and describe strict linear order relationships between different surface slots **415**. SurfaceSlot**1** SurfaceSlot**2** or (SurfaceSlot**1** SurfaceSlot**2**) means that both surface slots are located in the same linear order expression, but only one order of these surface slots relative to each other is possible such that SurfaceSlot**2** follows after SurfaceSlot**1**.

As another example, square brackets may be used to build the linear order expressions and describe variable linear order relationships between different surface slots **415** of the syntform **412**. As such, [SurfaceSlot1 SurfaceSlot2] indicates that both surface slots belong to the same variable of the linear order and their order relative to each other is not relevant.

The linear order expressions fro the linear order description **416** may contain grammatical values **414**, expressed by grammemes, to which child constituents correspond. In addition, two linear order expressions can be joined by the operator|(<<OR>>). For example: (Subject Core Object)|[Subject Core Object].

The communicative descriptions **480** describe a word order in the syntform **412** from the point of view of communicative acts to be represented as communicative order expressions, which are similar to linear order expressions. The government and agreement description **440** contains rules and restrictions on grammatical values of attached constituents which are used during syntactic analysis.

The non-tree syntax descriptions **450** are related to processing various linguistic phenomena, such as, ellipsis and coordination, and are used in syntactic structures transformations which are generated during various steps of analysis according to embodiments of the invention. The non-tree syntax descriptions **450** include ellipsis description **452**, coordination description **454**, as well as, referential and structural control description **430**, among others.

The analysis rules **460** as a part of the syntactic descriptions **102** may include, but not limited to, semantemes calculating rules **462** and normalization rules **464**. Although analysis rules **460** are used during the step of semantic analysis **150**, the analysis rules **460** generally describe properties of a specific language and are related to the syntactic descriptions **102**. The normalization rules **464** are generally used as transformational rules to describe transformations of semantic structures which may be different in various languages.

FIG. **5** illustrates exemplary semantic descriptions. The components of the semantic structures **104** are language-independent and may include, but are not limited to, a semantic hierarchy **510**, deep slots descriptions **520**, a system of semantemes **530**, and pragmatic descriptions **540**.

The semantic hierarchy **510** are comprised of semantic notions (semantic entities) and named semantic classes arranged into hierarchical parent-child relationships similar to a tree. In general, a child semantic class inherits most properties of its direct parent and all ancestral semantic classes. For example, semantic class SUBSTANCE is a child of semantic class ENTITY and the parent of semantic classes GAS, LIQUID, METAL, WOOD_MATERIAL, etc.

Each semantic class in the semantic hierarchy **510** is supplied with a deep model **512**. The deep model **512** of the semantic class is a set of the deep slots **514**, which reflect the semantic roles of child constituents in various sentences with objects of the semantic class as the core of a parent constituent and the possible semantic classes as fillers of deep slots. The deep slots **514** express semantic relationships, including, for example, "agent", "addressee", "instrument", "quantity", etc. A child semantic class inherits and adjusts the deep model **512** of its direct parent semantic class

The deep slots descriptions **520** are used to describe the general properties of the deep slots **514** and reflect the semantic roles of child constituents in the deep models **512**. The deep slots descriptions **520** also contain grammatical and semantic restrictions of the fillers of the deep slots **514**. The properties and restrictions for the deep slots **514** and their possible fillers are very similar and often times identical among different languages. Thus, the deep slots **514** are language-independent.

The system of semantemes **530** represents a set of semantic categories and semantemes, which represent the meanings of the semantic categories. As an example, a semantic category, "DegreeOfComparison", can be used to describe the degree of comparison and its semantemes may be, for example, "Positive", "ComparativeHigherDegree", "SuperlativeHighestDegree", among others. As another example, a semantic category, "RelationToReferencePoint", can be used to describe an order as before or after a reference point and its semantemes may be, "Previous", "Subsequent", respectively, and the order may be spatial or temporal in a broad sense of the words being analyzed. As yet another example, a semantic category, "EvaluationObjective", can be used to describe an objective assessment, such as "Bad", "Good", etc.

The systems of semantemes **530** include language-independent semantic attributes which express not only semantic characteristics but also stylistic, pragmatic and communicative characteristics. Some semantemes can be used to express an atomic meaning which finds a regular grammatical and/or lexical expression in a language. By their purpose and usage, the system of semantemes **530** may be divided into various kinds, including, but not limited to, grammatical semantemes **532**, lexical semantemes **534**, and classifying grammatical (differentiating) semantemes **536**.

The grammatical semantemes **532** are used to describe grammatical properties of constituents when transforming a syntactic tree into a semantic structure. The lexical semantemes **534** describe specific properties of objects (for example, "being flat" or "being liquid") and are used in the deep slot descriptions **520** as restriction for deep slot fillers (for example, for the verbs "face (with)" and "flood", respectively). The classifying grammatical (differentiating) semantemes **536** express the differentiating properties of objects within a single semantic class, for example, in the semantic class HAIRDRESSER the semanteme <<RelatedToMen>> is assigned to the lexical meaning "barber", unlike other lexical meanings which also belong to this class, such as "hairdresser", "hairstylist", etc.

The pragmatic description **540** allows the system to assign a corresponding theme, style or genre to texts and objects of the semantic hierarchy **510**. For example, "Economic Policy", "Foreign Policy", "Justice", "Legislation", "Trade", "Finance", etc. Pragmatic properties can also be expressed by semantemes. For example, pragmatic context may be taken into consideration during the semantic analysis.

FIG. **6** illustrates exemplary lexical descriptions. The lexical descriptions **103** represent a plurality of lexical meanings **612** in a specific language for each component of a sentence. For each lexical meaning **612**, a link **602** to its language-independent semantic parent may be established to indicate the location of a given lexical meaning in the semantic hierarchy **510**. The semantic hierarchy **510** together with the lexical descriptions of a specific language form the lexical-semantic hierarchy of the language, so when we talk about the specific language we can name it "the lexical-semantic hierarchy."

Once created semantic hierarchy **510** including the system of the universal semantic classes with their deep models, which are language-independent, said semantic hierarchy may then be used for creating syntactical and semantic models (lexical description=lexical–semantic hierarchy) of any natural language. When a new lexical meaning should be added to the lexical-semantic hierarchy, it should be supplied by its description, the considerable part of which is inherited from its parent semantic classes. So, at first, a location of the new lexical meaning in the semantic hierarchy should be determined. Since a dictionary entry may contain one or more lexical meanings, one or more semantic classes may be selected as parents for these lexical meanings. Additionally, a lexical meaning may be considered in different aspects, so each lexical meaning may be placed in one or more position of the semantic hierarchy. If a suitable semantic class doesn't exist, such semantic class may be created.

Each lexical meaning **612** in the lexical-semantic hierarchy **510** is connected with its deep model **512**, which is described in language-independent terms, and surface model **410**, which is language-specific. Diatheses can be used as the "interface" between the surface models **410** and the deep models **512** for each lexical meaning **612**. One or more diatheses **417** can be assigned to each surface slot **415** in each syntform **412** of the surface models **410**.

While the surface (syntactical) model **410** describes the syntactic roles of surface slot fillers, the deep model **512** generally describes their semantic roles. A deep slot description **520** expresses the semantic type of a possible filler, reflects the real-world aspects of the situations, the properties or attributes of the objects denoted by words of any natural language. Each deep slot description **520** is language-independent since different languages use the same deep slot to describe similar semantic relationships or express similar aspects of the situations, and the fillers of the deep slots **514** generally have the same semantic properties even in different languages. Each lexical meaning **612** of a lexical description of a language inherits semantic class from its parent and adjusts its deep model **512**.

In addition, the lexical meanings **612** may contain their own characteristics and also inherit other characteristics from language-independent parent semantic class as well. These characteristics of the lexical meanings **612** include grammatical values **608**, which can be expressed as grammemes, and semantic value **610**, which can be expressed as semantemes.

Every surface (syntactical) model **410** of a lexical meaning includes one or more syntforms **412**. Every syntform, **412** of a surface model **410** may include one or more surface slots **415** with their linear order description **416**, one or more grammatical values **414** expressed as a set of grammatical characteristics (grammemes), one or more semantic restrictions on surface slot fillers, and one or more of the diatheses **417**. Semantic restrictions on a surface slot filler are a set of semantic classes, whose objects can fill this surface slot. The diatheses **417** are the part of relationship **224** between syntactic descriptions **102** and semantic descriptions **104**, and represent correspondences between the surface slots **415** and the deep slots **514** of the deep model **512**.

When a new lexical meaning is added to the lexical-semantic hierarchy **510** to a determined position, comparing one or more example sentences with the new meaning against one or more semantic and syntactical models of selected positions inherited through the lexical-semantic hierarchy is executed. Such comparing may be executed manually or automatically by a specific computer program. As result, the inherited model may be narrowed or split in a case of partial mismatch between the example sentence with the new meaning and the one or more semantic and syntactical (surface) models wherein the partial mismatch occurs in one or more slots inherited through the lexical-semantic hierarchy.

Additionally, creating the new unit in selected position of the lexical-semantic hierarchy includes restricting one or more models of other units in the lexical-semantic hierarchy where said new unit may fill one or more slots of one of more model of the other units.

FIG. **7** illustrates another exemplary process flow diagram according to one or more embodiments of the invention. For a source sentence **702**, the lexical-morphological analysis **120**, the rough syntactic analysis **130**, the precise syntactic analysis **140**, and the semantic analysis **150** are performed by the methods, software, algorithms, computer systems, computer-readable media, and language analyzers/devices according to embodiments of the invention. For example, each of these analyses and method steps thereof can be adapted to be stored as software, algorithms, and computer-readable media, or alternatively, within computer systems and language analyzing devices; e.g., in a lexical analyzer **712** for performing the lexical and lexical-morphological analyses **120**, a rough syntactic analyzer **722** for performing the rough syntactic analysis **130**, a precise syntactic analyzer **732** for performing the precise syntactic analysis **140**, and a semantic analyzer **742** for performing the semantic analysis **150**, etc. As another example, one or more algorithms, computer systems, or analyzer can be used to perform one or more analyses and method steps as described in FIG. **1** and/or FIG. **7**.

Lexical Analysis

The lexical analysis **110** is performed on the source sentence **702** as represented in a source/input language, which may be any natural language, for which all the necessary language descriptions have been created. A source sentence **702** may be divided into a number of lexemes, elements, or units, including all the words, word forms, gaps, spacers, and punctuators, etc. present in the source sentence for building a lexical structure of the sentence. A lexeme is a meaningful linguistic unit that is an item in the vocabulary, such as the lexical descriptions **103** of a language.

FIG. **8** shows an exemplary lexical structure for a sentence **820**, "This child is smart, he'll do well in life." in English, where all words and punctuators are accounted for, having a total of twelve (12) elements **801-812** or entities, and nine (9) gaps **821-829**. The gaps **821-829** can be represented by one or more punctuators, blank spaces, etc.

From the elements or entities **801-812** of the sentence, a graph of its lexical structure is built. Graph nodes are coordinates of symbols of beginning and end of the entities and its arcs are words, gaps between the entities **801-812** (word forms and punctuators), or punctuators. For example, the graph nodes are shown in FIG. **8** as coordinates: 0, 4, 5, . . . , 44. Incoming and outcoming arcs are shown for each coordinate and arcs can be made for the corresponding entities **801-812** as well as the gaps **821-829**. The lexical structure for the sentence **820** can be used later during the rough syntactic analysis **130**.

Lexical Morphological Analysis

Referring back to FIG. **7**, the lexical-morphological analysis **120** is performed on the source sentence **702**.

During the lexical-morphological analysis **120** each element of the source sentence **702** are searched in order to find one or more word forms, which is not a space or a punctuator, assign one or more pairs of "lexical meaning-grammatical value" corresponding to each word form, and generate a lexical-morphological structure **750** for the source sentence **702**. For example, in the sentence **820**, elements **801-812** are found and among them, the word "he'll" is divided into two elements, "he'" and "ll", as shown in FIG. **8** as the element **806** and the element **807**.

As shown in FIG. **7**, the morphological descriptions **101** for the source language (e.g., the word-inflexion description **310** and the word-formation description **330**, etc.) and a lexical-semantic dictionary **714** are used to provide a set of lexemes for each word form. Each lexeme may correspond to one or more (usually multiple) word forms, one or more corresponding lexical meanings **612** and grammatical values **608** obtained from the lexical-semantic dictionary **714**, an their corresponding grammatical values **608** obtained from the morphological descriptions **101**. The grammatical values **608** are represented as a set of values of grammatical attributes (expressed in grammemes) of a word form. Examples of these grammatical attributes include, but are not limited to, the part of speech, number, gender, case, etc. A complete set of pairs of "lexical meaning-grammatical value" is then generated for each word form in the source sentence **702** and used to build the lexical-morphologic structure **750** for the source sentence **702**.

FIG. **9** illustrates an example of the lexical-morphological structure **750** having a complete set of pairs of "lexical meaning-grammatical value" for the sentence **820**. For example, "ll" may mean "shall" **912** and "will" **914** as its lexical meanings **612**. For the lexical meaning of "shall" **912**, the grammatical values **608** is <Verb, GTVerbModal, ZeroType, Present, Nonnegative, Composite_ll>, as shown in FIG. **9**. As another example, the grammatical value **608** for the lexical meaning "will" **914** is <Verb, GTVerbModal, ZeroType, Present, Nonnegative, Irregular, Composite_ll>.

During the initial stage of the lexical-morphological analysis **120**, lemmatization (searching and assigning lexemes) and obtaining pairs of lexical meaning-grammatical value from the lexical-semantic dictionary **714** are concurrently made. The lexeme of the word form, its lemma, and morphological grammatical values for all elements for the source sentence **702** are searched and found by using the lexical-semantic dictionary **714**. If there may be various grammatical values **608** for a word form found for a single category, the lexical-morphological structure **750** may include all the possible grammatical values **608** connected by "or".

For example, six pairs of "lexical meaning-grammatical value" are found for the word form "smart", as shown in FIG. **9**. As a result, the word form "smart" may have the same lexical meaning of "smart" but six (6) different grammatical values **608**. Depending on its presence in different parts of speech, the word form "smart" may be Adjective, Verb, Adverb, Noun, etc, and there may be three different grammatical values for Verb as the value of the "Part of speech" category, as shown in FIG. **9**. As another example, the word form "life" may have two lexical meaning-grammatical value pairs generated having the lexical meaning **902** of "life" paired with the grammatical value of <Adjective, DegreePositive, GTAdjectiveAttr> and lexical meaning **904** of "life" paired with <Noun, Nominative|Accusative, GTNoun, Singular>.

In addition, different lexical meanings may correspond to the same lexeme, for example, the lexeme "smart" as an adjective has the following lexical meanings with different semantics (as given, for example, in the Oxford Thesaurus), including 1) "well dressed, well turned out, fashionably dressed, etc."; 2) "fashionable, stylish, high-class, exclusive, chic, fancy, etc."; 3) "clever, bright, intelligent, sharp, sharp-witted, quick-witted, etc.", among others. These different lexical meanings have proper language-independent semantic parents, different deep models, and different surface models. During the lexical analysis stage, all these lexical meanings are generalized, but the whole list is stored/saved in order to use their surface and deep models for further analysis.

Since every lexical meaning in any given language goes back to the semantic class which is the parent of the lexical meaning and inherits some characteristics of the parent semantic class, a corresponding lexical description **103** with its surface model **410** and deep model **512** can be found in the lexical-semantic dictionary **714**. All the lexical descriptions **103** and the morphological descriptions **101** related to all the lexical meanings **612** of all word forms of the source sentence **702** are used in the lexical-morphological analysis **120**. Once a complete set of pairs of "lexical meaning-grammatical value" for the source sentence **702** are made, merging of the grammatical values **608** are performed.

FIG. **10** shows the results of merging of the grammatical values **608** for each lexeme of the sentence **820**, illustrating an exemplary merged lexical-morphological structure **1000** with merged grammatical values **608** for the entities **801-812** of the sentence **820**. As an example, the two pairs of "lexical meaning-grammatical value" for the word form "life" in the sentence **820** are merged into a generalized grammatical value **1002** to mean "life <Adjective|Noun, GTAdjectiveAttr|GTNoun>", which denotes, for the lexeme "life", the grammatical value expressed as "Adjective or Noun" at category Part OfSpeech and as "GTAdjectiveAttributive or GTNoun" at category GrammaticalType. As a result, the generalized grammatical value **1002** for "life" in the sentence **820** is <Adjective|Noun, GTAdjectiveAttri|GTNoun>. As another example, the two pairs of "lexical meaning-grammatical value" for the word form "ll" in the sentence **820** with the lexical meanings of "shall" **912** and "will" **914** can not be merged and for the entity **807** the two pairs of lexical meaning-grammatical value **1012**, **1014** remain to mean "shall" and "will" in the merged lexical-morphological structure.

Once the lexical-morphological structure **750** is constructed and generalized grammatical values, if generalization/merging is possible, are provided for each word form, a syntactic analysis is performed. The syntactic analysis may be performed in two steps, the rough syntactic analysis **130** and the precise syntactic analysis **140**, which are performed bottom-up and top-down, respectively.

Rough Syntactic Analysis

As shown in FIG. **7**, the rough syntactic analyzer **722** or its equivalents thereof is adapted to generate the graph **760** of the generalized constituents from the lexical-morphological structure **750** using the surface models **410**, the deep models **512**, and the lexical-semantic dictionary **714**. All the possible surface syntactic models for each element of lexical-morphological structure of the sentence are applied, and then all the possible constituents are built and generalized. Accordingly, all the possible syntactic descriptions and syntactic structures for the source sentence **702** are considered and, as a result, the graph **760** of the generalized constituents is built from a plurality of the generalized constituents. The graph **760** of generalized constituents reflects, on a surface model level, the relationships between the words of the source sentence **702**.

During the rough syntactic analysis **130**, every element of the source sentence **702** which is not a space or a punctuator is viewed as a potential core of a constituent. For example, in the sentence **820**, the elements **801-811** can be used as a potential core of a constituent and one or more constituents can be generated for the elements **801-811**.

The building of the graph **760** of generalized constituents starts with building those constituents which have only the core word form and further expands to build constituents of the next level by including neighboring constituents. For each pair of "lexical meaning-grammatical value" which corresponds to a non-trivial arc of lexical-morphological structure, its surface model **410** is initialized, attempting to attach other constituents in the surface slots **415** of the syntforms **412** of its surface model **410** to the right and the left neighboring constituents. If an appropriate syntform **412** is found in the surface model **410** of the corresponding lexical meaning, the selected lexical meaning may be the core of a new constituent.

The graph **760** of generalized constituents is first built as a tree, from the leaves to the root (bottom up). Building of additional constituents is performed bottom-up by attaching child constituents to parent constituents via filling the surface slots **415** of parent constituents to cover all the initial lexical units of the source sentence **702**.

The root of the tree is the main clause, representing a special constituent corresponding to various types of maximal units of a text analysis (complete sentences, enumerations, titles, etc.). The core of the main clause is generally a predicate. During this process, the tree actually becomes a graph, because lower-level constituents (the leaves) can be included into different upper-level constituents (the root).

Some of the constituents which are built for the same element of the lexical-morphological structure may be then generalized to obtain generalized constituents. Constituents are generalized by the lexical meanings **612**, by the grammatical values **414**, for example, by parts of speech, by their boundaries, among others. Constituents are generalized by the boundaries, since there may be very different syntactic relationships in the sentence, and the same word may be included in different constituents. As a result of the rough syntactic analysis **130**, the graph **760** of generalized constituents is built which represents the whole sentence.

FIG. **11** illustrates in further detail the rough syntactic analysis **130** according to one or more embodiments of the invention. The rough syntactic analysis **130** generally includes preliminary assembly **1110** of the constituents, building of generalized constituents **1120**, filtering **1170**, building of generalized constituent models **1130**, building **1140** a graph of generalized constituents, coordination processing **1150**, and restoring ellipsis **1160**, among others.

The preliminary assembly **1110** of the constituents during the rough syntactic analysis **130** is performed on the lexical-morphological structure **750** of the sentence to be analyzed, including certain word groups, the words in brackets, inverted commas, etc. Only one word in the group (the constituent core) can attach or be attached to constituents outside the group. The preliminary assembly **1110** is performed early during the rough syntactic analysis **130** before buildings of generalized constituents **1120** and building of the generalized constituent models **1130** to cover all the boundaries of the whole sentence.

Building of generalized constituents **1120** generally require that all possible pairs of the lexical meaning **612** and the grammatical value **414** are found or assigned for each of

the constituents and attach the surface slots of the child constituents thereof to each of the constituents. Lexical units of the source sentence **702** can form into core constituents at bottom levels. Each constituent can be attached to a constituent at a higher level if the surface slots **415** of the constituent at the higher level can be filled. Thus, the constituents are further expanded to include the neighboring constituents built at previous constituent building process until all of the possible constituents have been built to cover the entire sentence.

During rough syntactic analysis **130**, the number of the different constituents which may be built and the syntactic relationships among them are considerably large, some of the surface models **410** of the constituents are chosen to be filtered through the process of filtering **1170** prior to and after the building the constituents in order to greatly reduce the number of the different constituents to be considered. Thus, at the early stage of the rough syntactic analysis **130**, the most suitable surface models and syntforms are selected on the basis of a prior rating. Such prior rough ratings include ratings of lexical meanings, ratings of fillers, ratings of semantic descriptions, among others.

The filtering **1170** during the rough syntactic analysis **130** include filtering of a set of syntforms **412** performed prior to and during the building of generalized constituents **1120**. The syntforms **412** and the surface slots **415** are filtered a priori, and constituents are filtered after they are built. The process of the filtering **1170** distills out a number of syntforms including, but not limited to, those syntforms that do not correspond to the grammatical values of the constituent, those syntforms where none of the core slots can be filled, those syntforms with special slots which describe grammatical movement, among others. A special slot, such as relativization and question, presupposing a special lexeme (relative or interrogative pronoun), is filtered out if the special lexeme is not present in the sentence.

In general, the syntax forms (syntforms **412**) which do not have fillers for at least one surface slot can be filtered and discarded. In addition, those lexical meanings **612** which do not have syntforms **412** with filled surface slots **415** are filtered and discarded. The rough syntactic analysis **130** is impossible to succeed if there is no syntform and no filled surface slot, and as such the filtering **1170** is performed.

Once all possible constituents are built, the generalization procedure is performed for building of the generalized constituents **1120**. All possible homonyms and all possible meanings for elements of the source sentence which are capable of being present in the same part of a speech are condensed and generalized, and all possible constituents built in this fashion are condensed into generalized constituents **1122**.

A generalized constituent **1122** describes all the constituents with all the possible boundaries in a given source sentence which have a word form as the core constituent and various lexical meanings of this word form. Since the constituents are generalized, a single constituent for each lexical meaning corresponding to each entity of a sentence, including homonyms, is built, and their syntactic forms may be analyzed simultaneously.

Next, the building of generalized constituent models **1130** is performed and a set of models **1132** of generalized constituents having generalized models of all generalized lexemes are built. A generalized constituent model of a lexeme contains a generalized deep model and a generalized surface model. A generalized deep model of a lexeme includes the list of all of the deep slots which have the same lexical meaning for a lexeme, together with the descriptions of all the requirements for the fillers of the deep slots. A generalized surface model contains information about the syntforms **412**, where the lexeme may occur, about the surface slots **415**, about the diathesis **417** corresponding between the surface slots **415** and the deep slots **514**, and about the linear order description **416**.

The syntforms **412** and the surface slots **415** that are significant for this lexeme are selected with the help of the bit-mask. In addition, the models **1132** of the generalized constituents are used because a constituent is generalized not only by lexical meanings and syntactic forms of its core, but also by the fragments it fills. The use of the models **1132** of the generalized constituents reduces the number of wrong relationships and helps to optimize the process to build a syntactic tree so that all possible boundaries are considered.

The diathesis **417** is built during the rough syntactic analysis **130** as the correspondence between generalized surface models and generalized deep models. The list of all possible semantic classes for all the diatheses **417** of the lexeme is calculated for each surface slot **415**.

As shown in FIG. **11**, information from the syntforms **412** of the syntactic descriptions **102** as well as the semantic descriptions **104** are used to build the models **1132** of the generalized constituents. For example, dependent constituents are attached to each lexical meaning **612** and the rough syntactic analysis **130** may also need to determine whether a "candidate" constituent or a dependent constituent can be the filler of the corresponding deep slot of the semantic description **104** for a core constituent. Such compatibility analysis allows the wrong syntactic relationships to be discarded early.

Then, the building **1140** of the graph of the generalized constituents is performed. The graph **760** of generalized constituents which describes all possible syntactic structures of the entire sentence is built by linking and assembling the generalized constituents **1122** to each other. The building **1140** of the graph of the generalized constituents is organized via generating and processing of the queue of requests to attach one constituent to another constituent. In general, contact pairs of constituents representing contact groups of words in the sentence can be included in the request queue.

A constituent can be attached to different surface slots of another constituent and a child constituent can be attached to different parent constituents. In each case, a request for attachment of one constituent to another constituent can be generated. The requests can be processed by a subsystem, such as a dispatcher **1190**. If attachment to the selected surface slot is performed or found impossible, the request is removed from the queue of active request **1310** of the dispatcher **1190**.

One or more dispatching algorithms adapted to execute the processing of different requests can be included in the dispatcher **1190**. FIG. **13** is an exemplary dispatching rule according to one embodiment of the invention that can be written into dispatching algorithms for the dispatcher **1190**. Queues, including active requests queue **1310** and standby queue **1320**, among others, can be processed by the dispatcher **1190**. The active request queues **1310** as well as passive request queues in the standby queue **1320** are represented as circles.

Initially, all contacting constituent pairs are put into the active requests queue **1310**. When a new constituent pair appears in the set, the dispatcher **1190** receives a signal that a new constituent pair has appeared to be put unto the dispatcher queue. The dispatcher **1190** is adapted to process requests from the active requests queue **1310** through an attachment control **1330**. If no active (unfilled) slots are in a request, the request is deleted and put into a trash bin **1350**. Otherwise, the unfinished request is put in the standby queue **1320**. When all requests in the active requests queue **1310** have been processed, the dispatcher **1190** may try to refill the queue with requests from the standby queue **1320**. The dispatcher **1190** makes sure that at least one of the constituents involved in the request is changed and attached. The dispatcher **1190** stops its work when the active requests queue is empty and cannot be refilled.

The dispatcher **1190** or any devices, systems, computer-readable media, adapted to perform the building **1140** of the graph of the generalized constituents can wait and search for new constituent pairs in order to put these constituent pairs into the dispatcher queue, such as by keeping the right and left directions of the neighboring constituents of a constituent. For example, during attaching a child constituent to the parent constituents, the left constituent pair of the child constituent is added to the left of the parent constituent and the right constituent pair of the child constituent is added to the right of the parent constituent.

As shown in FIG. **11**, the coordination processing **1150** is also performed on the graph **760** of the generalized constituents. Coordination is a language phenomenon which is presented in sentences with enumeration and/or a coordinating conjunction, such as "and", "or", "but", etc. A simple example of a sentence with coordination—"John, Mary and Bill came home." In this case only one of coordinated child constituent is attached in the surface slot of a parent constituent during building **1140** the graph of the generalized constituents. If a constituent, which may be a parent constituent, has a surface slot filled for a coordinated constituent, then all coordinated constituents are taken and an attempt is made to attach all these child constituents to the parent constituent, even if there is no contact or attachment between the coordinated constituents. During coordination processing **1150**, the linear order and multiple filling possibility of the surface slot are determined. If the attachment is possible, a proform which refers to the common child constituent is created and attached. As shown in FIG. **11**, the coordination processor **1182** or other algorithms, devices, and computer subsystems can be adapted to perform the coordination processing **1150** using coordination descriptions **452** in the building **1140** of the graph of generalized constituents.

The building **1140** of the graph of the generalized constituents can be impossible without ellipsis restoration **1160**. Ellipsis is a language phenomenon which is represented by the absence of core constituents. Ellipsis can also be related with coordination. The process of the ellipsis restoration **1160** is also needed to restore a missing constituent. An example of an elliptical English sentence is "The president signed the agreement and the secretary [signed] the protocol." As discussed above, the ellipsis restoration **1160** can be used to generate the new request **1340** and new constituent pairs.

As shown in FIG. **11**, the ellipsis processor **1180** or other algorithms, devices, and computer subsystems can be adapted to perform the ellipsis restoration **1160**. In addition, the ellipsis descriptions **452** which contain proform models can be adapted to aid the ellipsis processor **1180** and process core ellipsis to build the graph **760** of generalized constituents. Proforms may be auxiliary elements inserted into a sentence when establishing non-tree links. A proform model may include templates (patterns) of syntforms. These proform templates determine the required surface slots and their linear order. All constituents in the sentence for each proform are searched and the possibility to attach the constituent to the first of the required slots of the syntform-template is determined.

The coordination processing **1150** and the ellipsis restoration **1160** are performed during each program cycle of the dispatcher **1190** after the building **1140** of the graph of the generalized constituents and then the building **1140** may continue, as indicated by an arrow of returning back **1142**. If the ellipsis restoration **1160** is needed and called upon during the rough syntactic analysis **130** due to, for example, the presence of constituents left alone without any parent constituents being attached to, only these constituents are processed.

The dispatcher **1190** stops when the active request queue **1310** is empty and cannot be refilled. The dispatcher **1190** can be a device, system, or algorithm, which keeps all the information about the constituents that have been modified. A constituent is considered modified if changes have been introduced to any of its properties which describe the sub-tree, including boundaries and the set of pre-child constituents. In addition, during the building **1140** of the generalized constituents **1122**, clause substitution is performed. Clauses for direct speech and proper names are substituted.

FIG. **12** is an exemplary graph **1200** of generalized constituents illustrating the graph of the generalized constituents for the sentence **820** "This child is smart, he'll do well in life." The constituents are represented by rectangles, each constituent having a lexeme as its core. Morphological paradigm (as a rule, the part of speech) of a constituent core is expressed by grammemes of the part of speech and displayed in broken brackets below the lexeme. A morphological paradigm as a part of word-inflection description **310** of morphological description **101** contains all information about word-inflection of one or more part of speech. For example, since "do" can have two parts of speech: <Verb> and <Noun> (which is represented by the generalized morphological paradigm <Noun&Pronoun>), two constituents for "do" are shown in the graph **1200**.

Links in the graph **1200** represent filled surface slots of the constituent core. Slot names are displayed on the arrows of the graph. The constituent is formed by the lexeme-core which may have outgoing named arrows which denotes surface slots **415** filled by child constituents together with child constituents themselves. An incoming arrow means attaching this constituent to a surface slot of another constituent. The graph **1200** is so complicated and has so many arrows, because it shows all relationships which can be established between constituents of the sentence **820**. Among them there are many relationships which, however, will be discarded. A value of said prior rough rating is saved by each arrow denoting a filled surface slot. Only surface slot and relationships with high rating scores will be selected first of all at the next stage of syntactic analysis.

Often several arrows may connect the same pairs of constituents. It means that there are different acceptable surface models for this pair of constituents, and several surface slots of the parent constituent may be independently filled by this child constituent. So, three surface slots named Idiomatic_Adverbial **1210**, Modifier Adverbial **1220** and AdjunctTime **1230** of the parent constituent "do<Verb>" **1250** may be independently filled by the child constituent "well<Adverb>" **1240** in accordance with surface model of the constituent "do<Verb>". Thus, roughly speaking "do<Verb>" **1250**+"well<Adverb>" form a new constituent with the core "do<Verb>" which is attached to another parent constituent, for example, to #NormalSentence<Clause> **1260** in the surface slot Verb **1270**, and to "child<Noun&Pronoun>" **1290** in the surface slot RelativClause_DirectFinite **1290** The marked element #NormalSentence<Clause>, being the "root", corresponds to the whole sentence.

Precise Syntactic Analysis

The precise syntactic analysis **140** is performed to build a syntactic tree, which is a tree of the best syntactic structure **770**, for the source sentence. Many syntactic structures can be built and the most probable syntactic structure is obtained as the best syntactic structure **770**. As shown in FIG. **7**, the precise syntactic analyzer **732** or its equivalents thereof is adapted to perform the precise syntactic analysis **140** and generate the best syntactic structure **770** on the basis of calculating ratings using a priori ratings **736** from the graph **760** of the generalized constituents. The priori ratings **736** include ratings of the lexical meanings, such as frequency (or probability), ratings of each of the syntactic constructions (e.g., idioms, collocations, etc.) for each element of the sentence, and the degree of correspondence of the selected syntactic constructions to the semantic descriptions of the deep slots **514**. Rating scores are then calculated and obtained/stored.

Hypotheses about the overall syntactic structure of the sentence are then generated. Each hypothesis is represented by a tree which is a subgraph of the graph **760** of the generalized constituents to cover the entire sentence, and rating is calculated for each syntactic tree. During the precise syntactic analysis **140**, hypotheses about the syntactic structure of the source sentence are verified by calculating several types of ratings. These ratings are calculated as the degree of correspondence of the fillers of the surface slots **415** of the constituent to their grammatical and semantic descriptions, such as grammatical restrictions (e.g., the grammatical values **414**) in the syntforms **412** and semantic restrictions on the fillers of the deep slots **514** in the deep models **512**. Another types of ratings are the degree of correspondence of the lexical meanings **612** to the pragmatic descriptions **540**, which may be absolute and/or relative probability ratings of the syntactic constructions as denoted by the surface models **410**, and the degree of compatibility of their lexical meanings, among others.

The calculated rating scores for each hypothesis may be obtained on the basis of a priori rough ratings found during the rough syntactic analysis **130**. For example, a rough assessment is made for each generalized constituent in the graph **760** of the generalized constituents and ratings scores can be calculated. Various syntactic trees can be built with different ratings. Rating scores are obtained, and these calculated rating scores are used to generate hypotheses about the overall syntactic structure of the sentence. To achieve this, the hypotheses with the highest rating are selected. These hypotheses are generated by advancing hypotheses about the structure of the child constituents which are most probable in order to obtain the most probable hypothesis about the overall syntactic structure of the sentence. Ratings are performed during precise syntactic analysis until a satisfactory result is obtained and a best syntactic tree having highest rating can be built.

Then, those hypotheses with the most probable syntactic structure of a whole sentence can also be generated and obtained. From syntactic structure **770** variants with higher ratings to syntactic structure **770** variants with lower ratings, syntactic structure hypotheses are generated during precise syntactic analysis until a satisfactory result is obtained and a best syntactic tree which has the highest possible rating can be built.

The best syntactic tree is selected as the syntactic structure hypothesis with the highest rating value available from the graph **760** of the generalized constituents. This syntactic tree is considered the best (the most probable) hypothesis about the syntactic structure of the source sentence **702**. Then, non-tree links in the tree are assigned, and accordingly, the syntactic tree transforms into a graph as the best syntactic structure **770**, representing the best hypothesis about the syntactic structure of the source sentence **702**. If non-tree relationships can not be assigned in the selected best syntactic tree, the syntactic tree with the second-best rating is selected as the best syntactic tree for further analysis.

When the precise syntactic analysis **140** is unsuccessful or the most probable hypotheses can not be found after initial precise syntactic analysis, returning back **734** for unsuccessful syntactic structure building from the precise syntactic analysis **140** back to the rough syntactic analysis **130** is provided and all syntforms, not just the best syntforms, are considered during the syntactic analysis. If no best syntactic trees are found or the system has failed to define non-tree relationships in all the selected "best" trees, then additional rough syntactic analysis **130** is performed taking into consideration "bad" syntform which were not analyzed before for the method of the invention.

FIG. **14** illustrates in further detail the precise syntactic analysis **140** performed to select the best syntactic structure **770** according one or more embodiments of the invention. The precise syntactic analysis **140** is performed top-down from the higher levels to the bottom lower levels, from the node of the potential top of the graph **760** of the generalized constituents down to its bottom-level child constituents.

The precise syntactic analysis **140** may contain various stages, including a preliminary stage, a stage **1450** for generating a graph of precise constituents, a stage **1460** for generating syntactic trees and differential selection of the best syntactic tree, a stage **1470** for generating non-tree links and obtaining a best syntactic structure, among others. The graph **760** of generalized constituents is analyzed during the preliminary stage which prepares the data for the precise syntactic analysis **140**.

The preliminary stage of the precise syntactic analysis **140** may include fragment specification **1410** and generating **1450** of a graph of precise constituents to obtain a graph of linear division **1440** and a graph of precise constituents **1430**, respectively. A linear divisional graph builder **1415** and builder **1490** of precise constituents may be adapted to process the fragment specification **1410** for obtaining the graph of linear division **1440** and the graph of precise constituents **1430**. In addition, the models **1132** of the generalized constituents can be used during the building **1450** of the graph of precise constituents.

During the precise syntactic analysis **140**, the precise constituents are built recursively. Proper constituents are generated backwardly and recursively. The precise constituents are built from the generalized constituents **1122** to initially perform the fragment specification **1410** thereon. The building **1450** of the graph of precise constituents may include reviewing the graph **1440** of linear division, recursively building the graph **1430** of the precise constituents which may contains fixed but not yet filled child slots, recursive performing the fragment specification **1410** for each graph arc lying on the way, and recursive filling a child slot to attach a child precise constituent built previously, among others. The generalized constituents **1122** are used to build the graph **1430** of precise constituents for generating one or more trees of precise constituents. For each generalized constituent, its possible boundaries and their child constituents are marked.

The stage **1460** for generating the syntactic trees is performed to generate the best syntactic tree **1420**. The stage **1470** for generating non-tree links may use the rules of establishing non-tree links and the information from syntactic structures **1475** of previous sentences to analyze one or more best syntactic trees **1420** and select the best syntactic structure **770** among the various syntactic structures. A generator **1485** for generating non-tree links is adapted to perform the stage **1470**.

As shown in FIG. **14**, the fragment specification **1410** of the precise syntactic analysis **140** is performed initially to consider various fragments which are continuous segments of a parent constituent. Each generalized child constituent can be included into one or more parent constituent in one or more fragments. Then, the graph of linear division **1440** (GLD) can be built as the result of the fragment specification **1410** to reflect the relationships of the parent constituent fragments with the core and child constituents. Additionally, the surface slot for the corresponding child constituents is assigned. The graph of linear division **1440** is the framework for building the graph **1430** of precise constituents. Precise constituents are nodes of the graph **1430** and one or more trees of precise constituents are generated on the basis of the graph **1430** of precise constituents.

The graph **1430** of precise constituents is an intermediate representation between the graph **760** of generalized constituents and syntactic trees. Unlike a syntactic tree, the graph **1430** of precise constituents can still have several alternative fillers for a surface slot. The precise constituents are formed into a graph such that a certain constituent can be included into several alternative parent constituents in order to optimize further analysis for selecting syntactic trees. Such an intermediate graph structure is rather compact for calculating structural ratings.

During the recursive stage **1450** for generating the graph of the precise constituents, the precise constituents are built traversally on the graph **1440** of linear division via the left and right boundaries of the core constituents. For each built path on the graph **1440** of linear division, the set of syntforms is determined; linear order is checked (verified) and rated for each of the syntforms. Accordingly, a precise constituent is created for each of the syntforms, and the building of precise child constituents is recursively initiated.

When a precise child constituent is built, an attempt is made to attach the precise child constituent to the precise parent constituent. When attaching child constituents, restrictions which the child constituents impose on the set of meanings of a parent constituent are taken into account, and the upper lexical rating of the link is calculated. When trying to attach each child constituent, two types of restrictions, which are represented by means of bit masks, are formed: the restriction (mask) on grammatical values of the parent constituent, which is received with the help of the agreement rule, and the restriction (mask) on grammatical values of the child constituent, which is received with the help of the agreement or government rule. Then, for each description of a deep slot which may have diathesis correspondence to the current surface slot, the following restrictions are obtained: the restriction on the lexical meanings of the parent constituent, the restriction on the possible lexical meanings of the child constituent and the restriction on the preferred lexical meanings of the child constituent (the set of preferred semantic classes in the description of the deep slot). Additionally, deep rating is obtained as a degree of conformity of the deep slot with these restrictions.

If there is a suitable identifying word combination in the sentence, for example, an idiom, which meets the restriction on parent lexical meanings, then the rating of the word combination is added to the deep rating. If none of the lexical meanings of child constituent meets the deep restrictions of this deep slot, attachment to this deep slot is impossible. The possibility of attachment to the other deep slots is checked. A deep slot which has the maximal value of the deep rating is selected.

The masks of grammemes for all child constituents which could be attached are merged. The mask on grammatical values of the parent constituent is used for calculating its grammatical value. For example, when child constituents are attached, the grammatical value of the syntactic form according to its correspondence with the child constituents is defined more precisely.

Coordination is also processed when a child constituent attached during the stage **1450**. For slots filled by coordination, there exists a need to check that not only the apex of coordination can be attached but its other components as well.

Additionally, ellipsis is also processed when a child constituent attached during the stage **1450**. Surface slots which are required in the syntform and do not permit ellipsis may be empty. In this case, when generating a precise constituent, a proform is placed in the empty slot.

As result of the stage **1450**, the graph of the precise constituents **1430**, which covers the whole sentence, is built. If the stage **1450** for generating the graph of the precise constituents has failed to produce the graph of the precise constituents **1430** which would cover the entire sentence, a procedure which attempts to cover the sentence with syntactically-separate fragments is initiated. In this case, a dummy (fictitious) generalized constituent is generated, where all generalized constituents of the sentence may be attached.

As shown in FIG. **14**, when the graph of precise constituents **1430**, which covers the sentence, was built, one or more syntactic trees can be generated at the step of generating **1460** during the precise syntactic analysis **140**. Generating **1460** of the syntactic trees allows generating one or more trees with a certain syntactic structure. Since surface structure is fixed in a given constituent, adjustments of structural rating scores, including punishing syntforms which are difficult or do not correspond to the style, or rating the communicative linear order, etc., may be made.

The graph of precise constituents **1430** represents several alternatives according to different fragmentation of the sentence and/or different sets of surface slots. So, the graph of precise constituents represents a set of possible trees—syntactic trees, because each slot can have several alternative fillers. The fillers with the best rating may form a precise constituent (a tree) with the best rating. Thus the precise constituent represents unambiguous syntactic tree with the best rating. At the stage **1460**, these alternatives are searched and one or more trees with a fixed syntactic structure are built. Non-tree links in the built trees are not defined yet. The result of this step is a set of best syntactic trees **1420** which have the best rating values.

The syntactic trees are built on the basis of the graph of precise constituents. For these precise constituents, syntactic forms, the boundaries of the child constituents and the surface slots are determined. The different syntactic trees are built in the order of descending of their structural rating. Lexical ratings cannot be fully used because their deep semantic structure is not defined yet. Unlike the initial precise constituents, every resulting syntactic tree has a fixed syntactic structure, and every precise constituent in it has only one filler for each surface slot.

During the stage **1460**, the best syntactic tree **1420** may generally be built recursively and traversally from the graph **1430** of precise constituents. The best syntactic subtrees are built for the best child precise constituents, syntactic structure is built on the basis of the given precise constituent, and child subtrees are attached to the generated syntactic structure. The best syntactic tree **1420** can be built, for example, by selecting a surface slot with the best quality among the surface slots of a given constituent and generating a copy of a child constituent whose sub-tree is the best quality subtree. This procedure is applied recursively to the child precise constituent.

On the basis of each precise constituent, the best syntactic tree with a certain rating score can be generated. This rating score can be calculated beforehand and specified in the precise constituent. After the best syntactic tree is generated, a new precise constituent is generated on the basis of the previous precise constituent. This new precise constituent in its turn generates a syntactic tree with the second-best value of the rating score. Accordingly, on the basis of the precise constituent, the best syntactic tree may be obtained, and a new precise constituent may be built.

For example, two kinds of ratings can be kept for each precise constituent during the stage **1460**, the quality of the best syntactic tree which can be built on the basis of this precise constituent, and the quality of the second-best syntactic tree. Also, the rating of the precise constituent includes the rating of the best syntactic tree which can be built on the basis of this precise constituent.

The rating of a syntactic tree is calculated on the basis of the following values: structural rating of the constituent; upper rating for the set of lexical meanings; upper deep rating for child slots; ratings of child constituents. When a precise constituent is analyzed to calculate the rating of the syntactic tree which can be generated on the basis of the precise constituent, child constituents with the best rating are analyzed in every surface slot.

During the stage **1460**, rating calculation for the second-best syntactic tree differs only in the fact that for one of the child slots, its second-best child constituent is selected. Any syntactic tree with a minimal rating loss relative to the best syntactic tree must be selected during this stage **1460**.

When the stage **1460**, additional restrictions on constituents are taken into account. Each precise constituent which gets into the best tree is checked for additional restrictions. If a constituent or one of its child constituents does not meet the restrictions, the constituent receives a mark that its best tree does not meet the additional restrictions. A check is performed to determine whether this subtree meets the additional restrictions.

The rules of additional restrictions are checked during the stage **1460** to make sure whether a constituent meets the restrictions but also suggest the steps which should be taken in certain slots so that the constituent will meet the restrictions. This approach can also significantly increase task-orientation of the search. The restrictions used during the stage **1460** can be defined for any surface slot and the corresponding deep slot. On the basis of the specified restrictions, the difference in quality between the best and second-best tree for this surface slot is calculated. As a result, a generation method is provided whereby a tree which meets the additional restrictions can be found as soon as possible.

Near the end of the stage **1460**, a syntactic tree with a fully-defined syntactic structure is built, i.e. the syntactic form, child constituents and surface slots that they fill are defined. Since this tree is generated on the basis of the best hypothesis about the syntactic structure of the initial sentence, this tree is called the best syntactic tree **1420**. The returning back **1462** from generating **1460** the syntactic trees to the building **1450** of the graph of precise constituents is provided when there are no syntactic trees with satisfactory rating generated, or the precise syntactic analysis is unsuccessful.

FIG. **15** illustrates schematically an exemplary syntactic tree according to one embodiment of the invention. In FIG. **15**, constituents are shown as rectangles, arrows show filled surface slots. A constituent has a word at its core (Core) with its morphological value (M-value) and semantic parent (Semantic class) and can have smaller constituents of the lower level attached. This attachment is shown by means of arrows named Slot. Each constituent has also a syntactic value (S-value), expressed as the grammemes of the syntactic categories thereof. These grammemes are the properties of the syntactic forms selected for the constituent during the precise syntactic analysis **140**.

FIG. **16** is an example of syntactic tree of the above mentioned sentence "This child is smart, he'll do well in life." This syntactic tree is generated as a result of the precise syntactic analysis **140** performed on the graph **1200** of the generalized constituents shown in FIG. **12**, and can be represented as a subgraph of the graph **1200** of the generalized constituents, according to one or more embodiments of the invention.

FIG. **17** is the same example of syntactic tree as shown in FIG. **16**, but modified into a tree. A rectangle shows a constituent with the selected lexical meaning of the core and its morphological paradigm in broken brackets, for example, Verb or Noun&Pronoun. The root of the syntactic tree **1700** is a particular value #NormalSentence, which serves as a clause value. The arrows are marked by the names of the surface slots, such as Modal, Verb, Subject, Demonstrative, etc., and for some of the surface slots, the corresponding rating scores are shown.

FIGS. **18-23** represent other syntactic trees **1800**, **1900**, **2000**, **2100**, **2200**, **2300** of best syntactic trees **1420**, generated as a result of the stage **1460** for the above mentioned sentence "This child is smart, he'll do well in life." These trees can be generated one after another, as soon as the stage **1470** to generate non-tree links on the previous syntactic tree is unsuccessful. The difference between the syntactic trees **1600**, **1700**, **1800**, **1900**, **2000**, **2100**, **2200**, **2300** lie in their structures, filled surface slots for some constituents, and/or the morphological paradigms for some constituents.

For example, the difference between the syntactic tree **1800** and the syntactic tree **1700** generally include the difference in the surface slots filled by the child constituent "well <Adverb>" in the parent constituent "do <Verb>". In the syntactic tree **1700**, the surface slot Modifier Adverbial **1730** is filled by the child constituent **1720** in the parent constituent **1710**. The rating score for filling of this surface slot is calculated and amounts to 0.25. In the syntactic tree **1800**, the surface slot AdjunctTime **1830** is filled by the child constituent **1820** in the parent constituent **1810** where the constituent **1810** is identical to the constituent **1710** and the constituent **1820** is identical to the constituent **1720**. The rating score for filling of this surface slot is calculated and amounts to 0.23. As a result, the tree rating **1740** for the syntactic tree **1700** is about 6.16 and the tree rating **1840** for the syntactic tree **1800** is about 6.15.

During the stage **1470**, non-tree links are specified for the best syntactic tree **1420**. Since, as a rule, non-tree links appear on the syntactic tree, and it is not a tree anymore, it is called a syntactic structure after the stage **1470**. Since many different non-tree links may be specified, several syntactic structures with defined non-tree links, i.e. with a fully-defined surface structure, may be obtained. The stage **1470** may result a syntactic structure **770** with the best rating—the best syntactic structure. During the stage **1470**, proforms are inserted into the best syntactic tree **1420**, non-tree links are specified, such as by performing ellipsis description **452** and coordination description **454**. Additionally, the grammatical agreement between each element of the sentence, which may be as a relationship of control, for example, a controller and a controlled element, using the referential and structural control description **456**, is checked. Additionally, syntactic structures **1475** of previous sentences may be used.

Non-tree links are established on the best syntactic tree **1420**—the tree of constituents with unambiguously fixed fillers of child slots. However, during the stage **1470**, many different non-tree links for the syntactic tree, which may be the best at the current moment, can be generated. Accordingly, several different syntactic structures with non-tree links may be built for each syntactic tree. These syntactic structures or syntactic structure variants generated from different syntactic trees may vary in the inserted proforms, their positions in the tree, and non-tree links. To be able to define an antecedent in the previous text, several of the syntactic structures **1475** of previous sentences from the previous syntactic analysis can be saved. The syntactic structure with the best rating is selected as the best syntactic structure **770**. If the stage **1470** is unsuccessful, the returning back **1472** to the stage **1460** is provided to obtain the next-best syntactic tree **1420** with the next value of rating score.

FIG. **24** is one example of a best syntactic structure **770**, which is obtained near the end of the stage **1470** for the sentence **820** "This child is smart, he'll do well in life." with non-tree links generated on the basis of the syntactic tree which is shown on FIG. **23**. A non-tree link of type "Anaphoric Model—Subject" **2410** is established from the constituent "child" **2420** to the constituent "he" **2430** to identify the subjects of the two parts of the complex sentence. Additionally, a proform PRO **2440** is inserted to establish a link between the controller ("child") **2420** and the controlled element ("smart") **2450**. As a result, the complement "smart" **2450** fills the surface slot "Modifier Attributive" **2460** of the controller "child" **2420** by means of a link of type "Control-Complement" **2470**.

During the stage **1470**, proforms are inserted. For every element of the sentence which can be a controller, its own proform is inserted. If a pronoun (or a proform substituted during the rough syntactic analysis) is controlled, a copy of the pronoun is uniformly made. As a result, every controlled element has a single controller. A controller can have several controlled element variants as different alternatives. Ideally, all available proforms are inserted. However, in the final syntactic tree, there may be only one of the control element variant remained. In addition, the set of meanings for a controlled element may be calculated from the controller; for example, a set of lexical meanings may be taken from the controller, a set of grammatical values may be limited by the agreement rule, etc. In general, the initial mask of a proform results in all the available meanings, whereas the initial mask of a pronoun may permit some meanings, e.g., as restricted by the morphological form of each element of the sentence. For example, after checking with agreement rules, the mask of a pronoun can be empty such that any linking or pairing up between the controller and its proform cannot be established. For example, in some cases, the gender of the controller and the pronoun may not agree; in these cases, only limited numbers of proforms inserted.

At the stage **1470**, the possibility to attach the controlled element to the surface slot is determined in a similar way as in attaching a child precise constituent in order to narrow the numbers of the qualified meanings of the controlled element. In general, the parent constituent may be left unchanged for a period of time without changing its grammatical value, and the lexical meaning of the parent constituent may be checked again at a later stage. Similarly, the controller may not be modified until a later stage.

The referential and structural control description **456** contains rules which can generate several alternative controlled elements during the stage **1470**. The search for controlled elements can be organized as a call of all the rules in the slots of the syntactic tree which have already been filled. Proforms may be sorted by their quality rating. Proforms which were substituted during the rough syntactic analysis but have not received a controller can be deleted from the syntactic structure.

During the stage **1470**, for every syntactic tree, a best syntactic structure with attached non-tree links can be generated, as a result. If no valid non-tree links have been generated, then the syntactic structure of the best syntactic tree **1420** is invalid. In this case, the second-best syntactic tree **1420** may be analyzed. If non-tree links have not been successfully established, a returning back **1472** to the stage **1460** is provided to obtain the next syntactic tree, which may have a different rating score, for generating another syntactic structure with non-tree links as the best syntactic structure. If none of the returning backs **1462** and **1472** for the precise syntactic analysis **140** is successful, the returning back **734** to the rough syntactic analysis **130** is provided. Additional rough syntactic analysis **130** can be performed with additional consideration of any syntforms which may not have been analyzed previously.

As a result of the rough syntactic analysis **130** and the precise syntactic analysis **140**, the syntactic structure with specified surface and deep slots is built. There may be some ambiguity left in grammatical values. The syntactic structure represents a full syntactic analysis of the sentence, indicates its surface and deep slots, and lexical meanings which have been unambiguously selected by this stage. Presence of non-tree links in the sentence determines, in the general case, generation of several different final structures according to different variants of establishing non-tree links. Final syntactic structures are sorted in the order of descending rating.

FIG. **25** illustrates a best syntactic structure **2500** generated for the sentence **820** during the precise syntactic analysis **140**. The best syntactic structure **2500** contains non-tree links **2530** and **2540**, the lexical meanings **612** with semantic classes as their semantic parents (**602**), and their grammatical values **608**. The semantic parents of the lexical meanings are shown by means of a colon and capital letters, for example, "child:SON_DAUGHTER". Grammatical values are displayed in broken brackets. Because the deep slots have already been determined in the end of precise analysis **140**, instead of the surface slots the corresponding deep slots are displayed in FIG. **25**: Agent, Locative, Agent, etc. To identify the elements "child" **2420** and "he" **2430** by means of the non-tree link **2530**, as it was displayed in FIG. **24**, the element "child:SON_DAUGHTER" **2510** is copied to the element **2520**, keeping the morphological value "Pronoun" in its grammatical value.

Semantic Analysis

As shown in FIG. **7**, the semantic analysis **150** is performed after one or more the syntactic trees are formed and the best one with the highest rating score found, a semantic analyzer **742** or its equivalents thereof is adapted to generate a semantic structure **780** using the lexical-semantic dictionary **714**, pragmatic context **744**, deep models **512**, and analysis rules **460**. The resulting semantic structure **780** of the source sentence **702** is built from the best syntactic structure **770** according to various applicable analysis rules. Constituents for the semantic structure **780** are constructed by applying diathesis correspondences between the surface (syntactic) and deep (semantic) slots of the constituents from the syntactic structure **770** and by applying the rules of semantic interpretation of the grammatical values of the constituents against a set of semantemes of various semantic categories. In one aspect, the semantic structure **780** includes a tree of deep constituents, each deep constituent having one semantic class.

Thus, the language-independent semantic structure **780** is generated during the semantic analysis **150** using the diatheses **417**, the deep models **512**, the analysis rules **460**, the lexical meanings descriptions of the source language as well as pragmatic context (as part of pragmatic descriptions **540**). The semantic analysis treats the syntactic structure of a sentence in any language as a surface representation of a language-independent semantic structure.

FIG. **26** is an exemplary process flow diagram illustrating the semantic analysis **150** according to one or more embodiments of the invention. A semantic structure **780** is built from a chosen syntactic structure **770** by performing steps **2610**, **2620**, **2630** of generating semantic structure, calculating communicative semantemes, and normalizating and calculating semantemes, among others. The syntactic structure **770** as the input data of the semantic analysis **150** may include specified deep slots and selected lexical meanings, the semantic structure **780** may be generated by substituting each lexical meaning in the source language with its language-independent semantic class and then confirming the linear order of the all the lexical meanings. Once the linear order is confirmed, the surface slots can be deleted when generating the semantic structure **780** since only the deep slots **514** and deep slots descriptions, etc., are remained during the building of the semantic structure **780**.

During the semantic analysis **150** to transform the syntactic structure **770** into the semantic structure **780**, deep correspondences for structural elements of the syntactic structure **770** are established, the grammatical values of the constituents from the syntactic structure **770** are interpreted against semantemes to represent language-independent semantic meanings, each lexical meaning is substituted with its language-independent semantic class, and semantemes with semantic features are generated. The resulting semantic structure **780** is a tree (containing established non-tree links), with language-independent semantic classes as nodes and a set of semantemes and deep slots as branches.

During the step **2610**, the semantic structure **780** is generated from the best syntactic structure **770** using the semantic descriptions and the lexical descriptions **103**, and the diathesis correspondences **417** between the surface slots **415** and the deep slots **514** for each constituent of the syntactic structure.

At the step **2620**, communicative semantemes for constituents in the semantic structure **780** are calculated using semantemes calculating rules **462** and communicative descriptions **480**. The semantemes calculating rules **462** can be used to semantically interpret the grammatical values of the constituents against a set of semantemes of various semantic categories. Once the communicative semantemes are calculated at step **2620**, all other semantemes can then be calculated, replacing grammemes with the resulting calculated semantemes. The communicative semantemes are used to express the communicative properties of a sentence, such as the standard linear order, the inverse linear order of a relative clause, or the linear order of an interrogative sentence.

At the step **2630** semantemes are then normalized and further calculated. The pragmatic context **744** and the analysis rules **460**, such as the semantemes calculating rules **462** and normalization rules **464**, may be used during semantemes normalization to remove language asymmetries. The semantic normalization rules **464** are applied to remove language asymmetries. For example, "all of any of the following functions" can be normalized to "all of the following functions". As another example, "each of all of us" can be normalized to "each of us". As still another example, "He can do it, can't he?" can be normalized to "He can do it."; since the deep slot of TagQuestion is filled, the constituents "can't he" are removed.

The semantic normalization rules **464** are lexicalized and linked to specific semantic classes and lexical meanings. There are two types of the semantic normalization rules **464**: rules to be used prior to calculating the semantemes for generating the semantic structure **780**; rules to be used after calculating the semantemes. A semantic class is connected with ordered lists of transformation rules of the first and second type. Thus, the semantic normalization rules **464** can be used prior to calculating the semantemes and after calculating the semantemes using the respective semantic normalization rules **464**.

In general, rules used during the semantic analysis **150** are applied to the constituents of the semantic structure **780** from the top down, from a parent constituent to child constituents. A constituent is analyzed with rules connected to the semantic class of its core, in the order of description. Rules connected with a certain class are used for all its children. In a child class there is a possibility to re-define inherited rules: add new rules, change the order of application, forbid inherited rules, etc.

The normalization rules **464** are applied to the semantic structure and modify it. Some of the semantemes calculating rules **462** may be used cyclically as long as their conditions are met. Use of semantemes calculating rules **462** leads, in particular, to substitution of language-dependent characteristics, grammemes, with universal characteristics—semantemes.

When the semantemes for different constituents are calculated at the step **2630** of normalizating and calculating semantemes, an additional procedure may be used. A semantemes calculating rule can check the presence of certain semantemes of other constituents. Such a rule can only work after all the semantemes which are specified in this rule have been calculated. To cope with this situation, the rules are started from the child constituents to the parent constituents. If a production refers to constituent semantemes which have not yet been calculated, the rule stops with a special value which says that the rule completion must be postponed. Then a traversal of the tree from the top down is made, starting the rules which were postponed at the first stage. Once again, a traversal of the tree from the child constituents to the parent is made by starting the rest of the postponed rules.

The result of the semantic analysis **150** is the semantic structure **780** of the source sentence built from the best syntactic structure **770** according to rules for the semantic analysis **150**. A semantic structure, unlike a syntactic structure, uses universal language-independent concepts and components, such as semantic classes, semantemes, deep slots, among others.

As shown in FIG. **26**, a dispatcher **2640** for dispatching semanteme rules is adapted to execute the normalization of the semantic structure **780** and calculating semantemes by applying the analysis rules **460**. As a result, every lexical meaning in the semantic structure **780** is substituted with its universal parent—a semantic class. Any possible differences of the child lexical meanings are saved in a list semantemes generated during the application of the analysis rules **460**. A description of a constituent in the final semantic structure **780** includes semantic classes which are parents for lexical meanings represented in the best syntactic structure **770**, semantemes which are calculated according to the analysis rules **460** or assigned to corresponding parent semantic classes, and child constituents. When there is a link to a child constituent, the deep slot that can be filled is specified. The semantic structure **780** is language-independent and may include, but is not limited to, a tree of deep constituents, deep constituents, and semantic classes which are the fillers of deep slots. Accordingly, the semantic structure **780** can be applied to describe the meanings of a sentence from any natural or artificial languages.

FIG. **27** illustrates an exemplary resulting semantic structure **2700** of the sentence **820**, "This child is smart, he'll do well in life." The deep constituents are represented by rectangles with a semantic class indicated inside, for example, DECLARATIVE_MAIN_CLAUSE, ACT, GOOD_BAD, etc. The semantemes which are calculated after applying the analysis rules **460** are displayed in broken brackets for each semantic class. For example, <Imperfective, Realis, Indicative, Present> is the semantemes for the semantic class BE_PREDICATIVE_STATE **2740**. Some of the applied analysis rules are displayed near rectangles with the semantic class. Deep slots are represented as arrows and named; for example, Object, Agent, Locative, etc. Non-tree links are represented as dotted arrows.

The method and process flow as described herein can be adapted into one or more computer-readable media or one or more algorithms in order to convert a natural-language sentence into its language-independent semantic structure. The one or more computer-readable media or one or more algorithms of the invention can be implemented on one or more analyzers, devices, or computer systems, adapted to perform a single analysis or just a couple of the analyses as described herein and linked together afterward. The algorithm of obtaining the semantic structure is fairly complex, as there are ambiguities at each step, and from a multitude of parsing variants only the most probable one is selected, based on the ratings which take into account semantic, stylistic and pragmatic factors and statistical data. In one aspect, computer-readable media or one or more algorithms may be adapted to perform one or more the lexical-morphological analysis **120**, the rough syntactic analysis **130**, the precise syntactic analysis **140**, and the semantic analysis **150**,

During each step shown in FIG. **1** and FIG. **7**, the user of the computer system can view and select each of the interim and resulting structures. By performing the lexical, morphological and syntactic analyses of a sentence, a syntactic structure as a tree of generalized constituents can be established. The syntactic structure of a sentence is transformed into a semantic structure by semantic interpretation of language-specific elements of the syntactic structure of the sentence and a tree of surface constituents are transformed into a tree of deep constituents and a language-independent semantic structure is formed.

A computer system implemented as a computer program with its own interface or as part of another system in accordance with the method of the invention includes means for entering natural-language text; means for segmenting text into sentences, words, letters, and non-text symbols; means for lemmatization and finding for each source word form a complete set of its grammatical and lexical meanings; means for constructing, in accordance with the model of each lexical meaning, constituents which are the realizations of these models in a given sentence; means for constructing one or more generalized constituents from constituents constructed by using various models available for each lexical meaning of a source word form; means for building a graph of generalized constituents covering all the hypotheses about the possible syntactic structures of the sentence; means for calculating a rough rating of constituents which are included into generalized constituents; means for generating hypotheses about the most probable precise structure of the sentence based on the rough ratings and for selecting the structure with the highest value of the rating; means for calculating the precise ratings for the selected, most probable syntactic structure constituents which are included into generalized constituents; means for establishing non-tree links; means for establishing correspondences for each surface slot of each constituent in the tree of constituents with deep slots; means for calculating the set of semantemes of each constituent on the basis of the set of grammemes; means for substituting each lexical meaning in the semantic tree with its language-independent semantic class; means for storing in a database the constructed semantic structure for further use in other applications.

In the computer system, each element of the lexical structure is considered a potential lexical core of the constituent. The means for constructing a constituent may include means for determining all the possible boundaries of the constituents; means for matching the surface models of possible lexical meanings with selected fragments of a given sentence; means for initializing the surface models of possible lexical meanings.

In addition, the means for constructing generalized constituents from constituents constructed by using various models use data about the deep and surface models of the lexical meanings stored in a lexical-semantic dictionary may include means for generalizing surface models; means for generalizing deep models; means for constructing generalized diatheses. The means for building a graph of generalized constituents may include a means for linking the constructed constituents to the surface slots of the parent constituents taking into account the linear word order.

Further, the means for calculating ratings for the selected syntactic structure of a constituent are based on individual ratings of the lexical meanings, ratings of each of the syntactic constructions (e.g., idioms, collocations, etc.) for each element of the sentence, and the degree of conformity of the selected syntactic construction to the semantic descriptions of the deep slots. The means for building a graph of generalized constituents includes means for filtering the constituent models being generalized.

The means for generating hypotheses about the most probable precise structure of the sentence may include means for generating syntactic trees; means for generating the non-tree links; means for verifying the most probable hypothesis by generating specific hypotheses about the structure of dependent constituents; means for choosing the best syntactic structure, i.e. for selecting the tree from the generalized graph. Further, the means for establishing non-tree links for coordination processing, ellipsis, and referential relationships and the means for substituting each lexical meaning in the semantic tree with its language-independent semantic class with registering distinctive semantic features of the lexical meanings. Also, the computer system can implement all the methods, steps, actions automatically.

Embodiments of the invention allow achieving a high accuracy of recognition of the meanings of natural-language sentences, ability to analyze complex language structures, and correct conveyance of information encoded in the sentences. Said effect has been obtained by using exhaustive language descriptions, which include language-independent semantic representations and integral models for describing the syntax and semantics of sentences of various languages. Also, said effect has been obtained by implementation of a two-step analysis algorithm (rough and precise syntactic analyses) which uses the linguistic data of various levels to calculate probability ratings and generates the most probable syntactic structure **770** variants first.

This approach is also different from the known art in that it is based on principles of integral and purpose-driven recognition. This principle consists in that hypotheses about the structure of the part of a sentence are verified within the hypotheses about the structure of the whole sentence. This approach avoids analyzing numerous parsing variants which are known to be invalid.

The invention is superior to the known art as it uses various natural language descriptions which can reflect all the complexities of a language, rather than simplified or artificial descriptions, without the danger of a combinatorial explosion. As result, a generalized data structure, such as a semantic structure, is generated and used to describe the meaning of one or more sentences in language-independent form, applicable to automated abstracting, machine translation, control systems, internet information retrieval, etc.

A typological analysis for the invention was performed for various linguistic families, including Indo-European (Slavic, Germanic, and Romanic languages), Finno-Ugrian, Turkic, Oriental, and Semitic. Embodiments of the invention may be applied to many languages, including, but not limited to, English, French, German, Italian, Russian, Spanish, Ukrainian, Dutch, Danish, Swedish, Finnish, Portuguese, Slovak, Polish, Czech, Hungarian, Lithuanian, Latvian, Estonian, Greek, Bulgarian, Turkish, Tatar, Hindi, Serbian, Croatian, Romanian, Slovenian, Macedonian, Japanese, Korean, Chinese, Arabic, Hindi, Hebrew, Swahili, among others.

While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

We claim:

1. A method for analyzing natural language texts using a lexical-semantic hierarchy, the method comprising:

creating, by a computing device, the lexical-semantic hierarchy comprising at least one language-independent semantic class, wherein the semantic class includes one or more semantic attributes and one or more models;

creating at least one language-specific lexical class associated with the lexical-semantic hierarchy, wherein the language-specific lexical class includes one or more semantic and syntactical attributes and one or more models, and wherein the semantic and syntactical attributes and models are inheritable from respective parent units to child units;

creating an instance of the lexical-semantic hierarchy in a memory of the computing device;

identifying a new lexical meaning in a natural language;

identifying at least one candidate position of the new lexical meaning in the lexical-semantic hierarchy in the memory of the computing device on the basis of a dictionary entry for the new lexical meaning;

comparing one or more example sentences comprising the new lexical meaning against one or more semantic and syntactical models of the identified candidate position in the lexical-semantic hierarchy;

creating a new unit in the identified candidate position of the lexical-semantic hierarchy;

creating a syntactical and semantic model for the new unit;

storing the new unit and the created syntactical and semantic model in the memory of the computing device;

receiving a sentence in the natural language; and

representing, using the syntactical and semantic model of the new unit, the sentence in a language-independent form.

2. The method of claim **1**, wherein said creating the new unit in the identified candidate position of the lexical-semantic hierarchy is based at least in part upon the comparing of the example sentences comprising the new lexical meaning.

3. The method of claim **1**, wherein identifying the candidate position of the new lexical meaning in the lexical-semantic hierarchy further comprises at least one of: selecting a parent semantic class or creating a new semantic class for the new meaning.

4. The method of claim **1**, wherein creating the new unit in the identified candidate position of the lexical-semantic hierarchy further comprises at least one of: narrowing or splitting the inherited model responsive to detecting a partial mismatch between the example sentence with the new lexical meaning and the one or more semantic and syntactical models, wherein the partial mismatch occurs in one or more slots inherited through the lexical-semantic hierarchy.

5. The method of claim **1**, wherein creating the new unit in the identified candidate position of the lexical-semantic hierarchy further comprises restricting one or more models of other units in the lexical-semantic hierarchy where said new unit fills one or more slots of one of more models of the other units.

6. The method of claim **1**, further comprising:

creating a plurality of language-specific surface models for syntactic descriptions; and

creating diatheses for the syntactic descriptions to serve as an interface between the language-specific surface models and language-independent deep models of semantic descriptions.

7. The method of claim **6**, further comprising:

for each lexical meaning associated with a lexical description, creating a link between the lexical meaning and its language-independent semantic parent, wherein the link indicates a location of a given lexical meaning in the lexical-semantic hierarchy.

8. The method of claim **1**, wherein representing the source sentence in the language-independent form comprises determining a language-independent semantic structure of the source sentence.

9. The method of claim **8**, further comprising translating the source sentence to a second natural language using the language-independent semantic structure of the source sentence.

10. A computer system, comprising:

a memory for storing data for access by an application program being executed on a computer system, wherein the data relates to a syntactical and semantic model of a natural language, the data comprising a semantic description of entities expressed in the natural language, parametric characteristics of the natural language, and semantic relations with entities of the natural language; and

a processor, coupled to the memory;

wherein the memory is configured to store a data structure, the data structure comprising:

a plurality of language-independent entities represented by a plurality of semantic classes, wherein the semantic classes are arranged into a hierarchy, wherein each of the plurality of semantic classes includes at least one semantic attribute and a semantic model, and wherein the semantic attributes and the semantic models are inherited from parent units to child units;

a plurality of descriptions of semantic relations with the entities, wherein the descriptions of semantic relations are represented by a hierarchical sequence of elements;

a plurality of syntactic descriptions of the natural language, wherein one or more of the plurality of syntactic descriptions are associated with one or more semantic descriptions and one or more lexical descriptions of the natural language;

a plurality of lexical descriptions of the natural language, wherein one or more of the plurality of lexical descriptions of the natural language are associated with one or more of said syntactical descriptions and one or more of said semantic descriptions; and

a plurality of morphological descriptions of the natural language, wherein one or more of the plurality of morphological descriptions of the natural language are associated with one or more of said plurality of lexical descriptions of the natural language, wherein the processor is configured to:

receive a source sentence in a source language,

analyze the source sentence using at least one of the plurality of language-independent entities, and

represent the source sentence in a language-independent form, using at least one of the plurality of assigned descriptions of semantic relations, at least one of the plurality of syntactic descriptions of the natural language, at least one of the plurality of lexical descriptions of the natural language, and at least one of the plurality of morphological descriptions of the natural language.

11. The computer system of claim **10**, wherein said plurality of syntactic descriptions of the natural language further comprises:

a plurality of syntactical attributes describing syntactical properties and phenomena of the language;

a plurality of surface models of lexical meanings of the language, wherein each of the plurality of surface models is associated with one or more syntactic descriptions of one or more lexical meanings;

a plurality of analysis rules, wherein each of the plurality of analysis rules is associated with one or more syntactic descriptions of one or more lexical meanings;

a plurality of surface slot descriptions, wherein at least one of the plurality of surface slot descriptions is associated with one or more surface models of one or more lexical meanings; and

a plurality of non-tree syntax descriptions, wherein each non-tree syntax description is associated with one or more element of syntactic descriptions.

12. The computer system of claim **11**, wherein each surface model of lexical meanings comprises a plurality of syntactic forms, and wherein said syntactic form further comprises:

a plurality of surface slots, wherein each of the plurality of surface slots is associated with one or more syntactical roles of the lexical meaning as part of lexical description;

a linear order description;

a plurality of diatheses, wherein each diathesis connects a surface slot in the syntactic form with one or more deep slots comprised by a semantic description;

a plurality of grammatical values associated with one or more element of the syntactic form;

a plurality of government and agreement descriptions associated with one or more elements of the syntactic form; and

a plurality of communicative descriptions associated with one or more elements of the syntactic form.

13. The computer system of claim **11**, wherein said analysis rules comprises at least one semanteme calculation rule and at least one normalization rule, wherein the semanteme calculation rule is utilized in mapping syntactical properties into semantic properties.

14. The computer system of claim **11**, wherein said non-tree syntax description of a natural language comprises a description of an ellipsis description, coordination description, referential description or a structural control description.

15. The computer system of claim **11**, wherein the plurality of surface models is a plurality of language-specific descriptions, and wherein diatheses serve as an interface between the language-specific surface models of the syntactic descriptions and language-independent deep models of semantic descriptions.

16. The computer system of claim **10**, wherein the semantic description of a natural language further comprises:

a plurality of deep slot descriptions, wherein each of the deep slot reflects a semantic relation in a sentence;

a plurality of semantemes; and

a plurality of pragmatic descriptions.

17. The computer system of claim **10**, wherein for each lexical meaning associated with a lexical description, a link is established between the lexical meaning and its language-independent semantic parent, wherein the link indicates a location of a given lexical meaning in a semantic hierarchy.

18. A computer-readable non-transitory storage medium comprising executable instructions that, when executed by a processor, cause the processor to:

create a lexical-semantic hierarchy comprising at least one language-independent semantic class, wherein the semantic class includes one or more semantic attributes and one or more models;

create at least one language-specific lexical class associated with the lexical-semantic hierarchy, wherein the language-specific lexical class includes one or more semantic and syntactical attributes and one or more models, and wherein the semantic and syntactical attributes and models are inheritable from respective parent units to child units;

create an instance of the lexical-semantic hierarchy in the memory;

identify a new lexical meaning in a natural language;

identify at least one candidate position of the new lexical meaning in the lexical-semantic hierarchy in the memory on the basis of a dictionary entry for the new lexical meaning;

compare one or more example sentences comprising the new lexical meaning against one or more semantic and syntactical models of the identified candidate position in the lexical-semantic hierarchy;

create a new unit in position of the lexical-semantic hierarchy;

create a syntactical and semantic model for the new unit;

store, in said memory, the new unit and the created syntactical and semantic model;

receive a sentence in the natural language; and

represent, using the syntactical and semantic model of the new unit, sentence in a language-independent form.

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